RESEARCH PAPER

Immersive technologies & digital games for school disaster preparedness

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#1 Intro

1.1 Background

I hear, and I forget
I see, and I remember
I do, and I understand.

- Ancient Chinese proverb (Confucius 551 BC)

The age of immersive digital learning is here. An affordable smartphone and a five dollar cardboard headset can immerse anyone into an alternative virtual reality, or augment the one around them. Extended reality (XR) immersive technologies and serious digital games are quickly becoming accessible to a huge number of people across the world, including the developing world, via the rise of smartphones and evolution of the technology to become more affordable and accessible. This technological landscape is changing and improving literally as these words are being read.

The world is still grappling with the best ways to harness the power of these technologies. Some applications can be tokenistic and capitalise merely on the “wow factor” of being immersed in VR or AR for the first time. However, one area where particularly VR and serious games have been consistently used over the past decade with huge benefits is in training. Security, aviation and medical organisations and institutions saw very early on the benefits of training soldiers, pilots or doctors in virtual space where they could make mistakes and not risk losing their, or someone else’s, life. The field of education has also embraced XR for learning, though research on the effects of immersion on children is still in infancy stages.

Given the potential for XR on training, dangerous events and education, these technologies are also being applied to the field of emergency management and disaster preparedness, providing a realistic and safe space to prepare for crises and practice how to respond and harness the benefits of XR to improve learning outcomes and retain life saving information. Applications of serious digital games and immersive technologies range widely in the field of disaster preparedness, from first aid training to disaster drills to gamification techniques providing educational key messages. The Red Cross Red Crescent (RCRC) Movement is increasingly using immersive technologies for a range of aims, including building empathy, fundraising, awareness raising and behaviour change. However to date there is little use of these technologies at scale for school based disaster risk reduction and preparedness, although some examples do exist.[1] XR in the RCRC Movement is still in an experimental stage and has yet to be applied in a systematic way that looks at the gaps in traditional approaches and uses the unique affordances of these new media technologies to add pedagogical and behavioural value to the auxiliary role of the Red Cross Red Crescent Movement.

Red Cross and Red Crescent National Societies (NS) across the world contribute to disaster risk reduction and preparedness in public schools and this is an important component of Red Cross Red Crescent programming globally. There is huge potential for XR technologies and serious games to address many of the shortcomings of traditional school based DRR (SBDRR) and contribute to SBDRR's aims including helping children and teachers learn about hazards and practice responding, for example escape techniques through immersion in virtual hazards and emergency situations. XR can be particularly helpful to analyse how students and teachers behave in an emergency, in order to improve preparedness, and how they respond and cope with hazards.

This research paper presents the current SBDRR and XR technological landscape, analyses the shortcomings of traditional forms of SBDRR and how XR has the potential to address these. It also synthesises and presents a range of learning on the inception, design, production, distribution, partnership models and scalability of a full range of XR technologies from gaming apps used on mobile phones to augmented reality applications that have the potential to turn schools into disaster zones in seconds. The research stresses the enormous potential of XR for SBDRR alongside cautioning that any use of XR must not recreate DRR education as it already is, but utilise the unique affordances of the technology to bring added value to what is already in practice with other learning modalities. The technological landscape is examined in light of the realities of the RCRC Movement with an emphasis on the potential for scalability across multiple National Societies. A series of possible models, learning points and recommendations are presented that aim to benefit the Global Disaster Preparedness Centre (GDPC) and the broader disaster preparedness and risk reduction community and contribute to determining the next strategic XR steps of the Red Cross Movement in school disaster preparedness and risk reduction.

1 For example the GDPC has built various digital app games targeted at children that are used in schools, and the Asia Pacific Disaster Resilience Centre has built a fire and ship evacuation VR simulations that are used in schools in the Philippines, Nepal, Republic of Korea, Mongolia, Singapore, Thailand, Vietnam and Indonesia.

1.2 Methodology

This research paper (meta-analysis and literature review) was commissioned in March 2019 by the Global Disaster Preparedness Centre in response to the following disaster preparedness learning question: *How does GDPC and American Red Cross International Services best leverage the potential of serious games and virtual reality[2] to be an effective way of supporting disaster preparedness programming in schools?*

The goal of the research is to provide information and options to all organisations globally interested in pursuing immersive technologies and serious gaming as a disaster preparedness educational tool for schools. It does this through two methods; this literature review and meta analysis that highlight key learning points to be applied for future deployment of this type of technology for school preparedness; and ten case studies[3] that document the intersection of effective emerging technologies and disaster risk reduction and preparedness education, capturing the breadth of innovative technologies related to school safety and identifying good practices, effective approaches, and technological features that support disaster preparedness programming in schools. Case studies were selected based on their relevance to SBDRR and the work of the GDPC, the desire to have a range of technologies and innovations represented and examples from both within and external to the Red Cross Red Crescent Movement. The meta-analysis looks at the shortcomings of traditional SBDRR and provides solutions and new models with XR technologies and innovative practices.

Information contributing to this research and supporting case studies was gathered using a range of methods including semi-structured interviews with over 20 organisations[4] including XR experts from academic institutions, digital agencies and research consultancies and focal points who have developed XR experiences with/for humanitarian agencies. An extensive review of XR research literature and experiences was conducted, covering serious gaming and extended reality: augmented and virtual. The authors' own expertise in the XR field was also applied.

2 *The research question was expanded to consider other immersive technologies including augmented reality*
3 *See Annex A, case studies*
4 *See full list in Annex F, Interviews*

1.3 Definitions

SBDRR definitions

IFRC defines disaster preparedness as: *"measures taken to prepare for and reduce the effects of disasters. That is, to predict and, where possible, prevent disasters, mitigate their impact on vulnerable populations, and respond to and effectively cope with their consequences."*[5]

5 https://media.ifrc.org/ifrc/what-we-do/disaster-and-crisis-management/disaster-preparedness/

Disaster Risk Reduction (DRR) *"aims to reduce the damage caused by natural hazards like earthquakes, floods, droughts and cyclones, through an ethic of prevention."*[6]

School based disaster preparedness or risk reduction is the application of the above in the school community and targets everyone involved in the teaching and learning activities (students, teachers, education personnel, support staff, headteachers).

Technology Definitions

XR (extended reality): Extended reality, also known as cross-reality and hyper-reality, is an umbrella term that encompasses human-machine interactions generated by computer technology with devices or wearables to create real and virtual environments which include VR, AR and in this research paper also enompasses mixed reality as part of XR.

Mixed reality (MR): Mixed reality is a hybrid definition combining both AR and VR.

Virtual Reality (VR): Virtual Reality is a technology that creates an immersive experience and content in most cases using a VR headset, a head-mounted display (HMD) or a fully immersive space. The current reality viewed by the user is replaced with a new computer generated environment in which the user is isolated from the real world.

Augmented Reality (AR): Augmented reality is an immersive technology superimposing layers of digital content into the physical world to enhance the user's real world experience.

Serious Games (SGs): games whose primary purposes are training and education, rather than pure entertainment.

Haptic technologies: Haptic technology, also known as kinaesthetic communication or 3D touch, refers to any technology that can create an experience of touch by applying forces, vibrations, or motions to the user.[7]

Simulation: In science, a simulation is the creation of a model that can be manipulated logically to decide how the physical world works.[8] Simulation has become the defacto design technique for all control systems design of today. In computers, a simulation (or "sim") is an attempt to model a real-life or hypothetical situation on a computer so that it can be studied to see how the system works. By changing variables in the simulation, predictions may be made about the behaviour of the system. It is a tool to virtually investigate the behaviour of the system under study.[9]

Avatar: refers to a representation or a manifestation of a particular person or character, usually used in video games, virtual experiences and internet applications. An avatar can be used to represent the self or other characters in the virtual space.

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6 *https://www.unisdr.org/who-we-are/what-is-drr*
7 *https://en.wikipedia.org/wiki/Haptic_technology*
8 *Dr. Richard Gran, https://www.youtube.com/watch?v=OCMafswcNkY*
9 *Banks, J; J. Carson; B. Nelson; D. Nicol (2001). Discrete-Event System Simulation.*

#2 Context: School disaster preparedness and technology landscape

2.1 School disaster preparedness in the Red Cross Red Crescent Movement

2.1.1 Overview

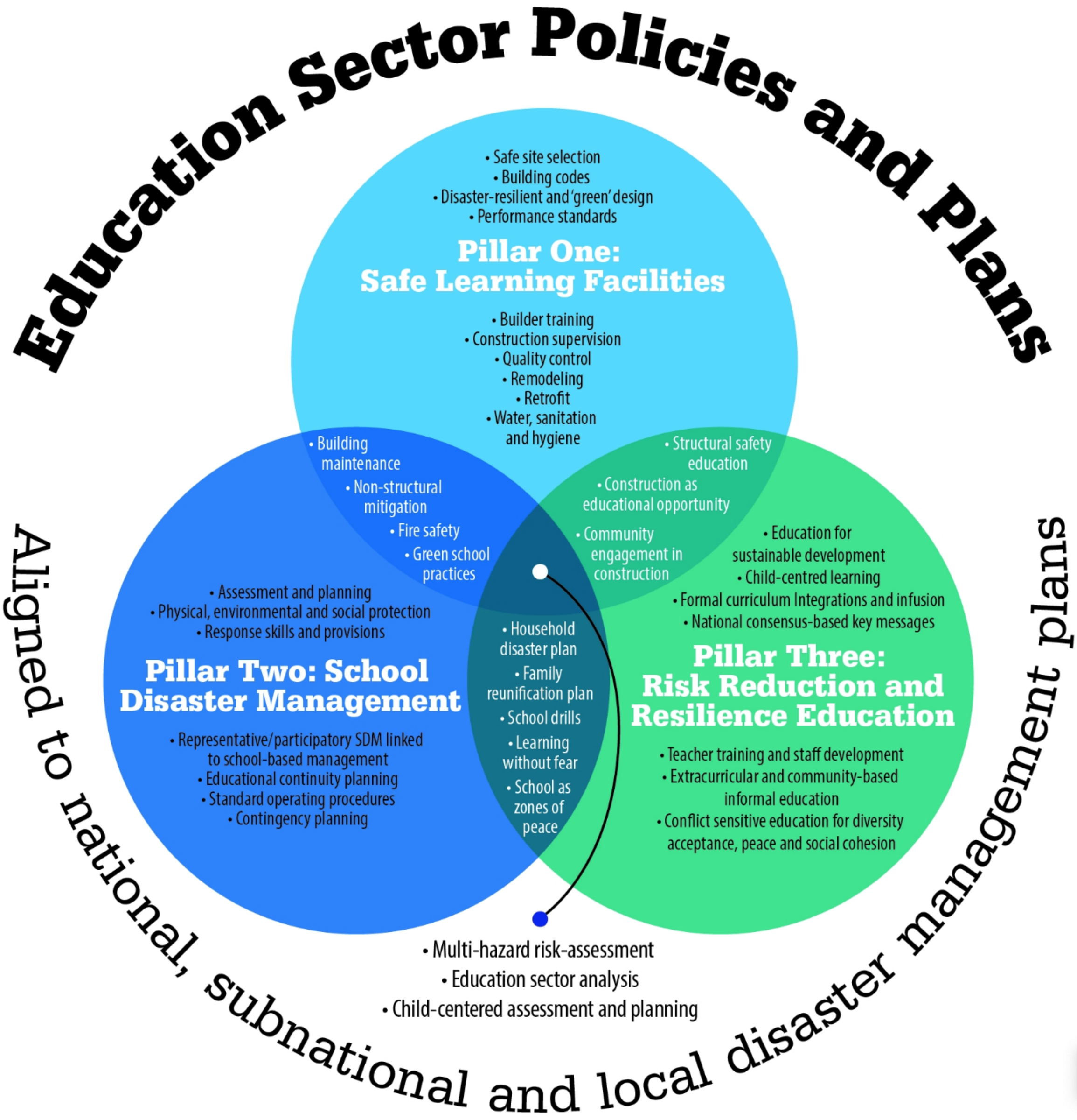
Red Cross Red Crescent National Societies across the world contribute to disaster risk reduction and preparedness in public schools and this is an important component of Red Cross Red Crescent programming globally. Typical school-based activities of Red Cross National Societies include disaster risk reduction, first aid, hygiene and health promotion, road safety and water and sanitation. The activities are typically run through Red Cross Red Crescent Disaster Management and Health programmes. National Societies have a unique position to influence school safely thanks to their existing relationships with national governments and support from a large number of volunteers.

For school disaster preparedness and risk reduction, Red Cross National Societies work across the three pillars of the **Comprehensive School Safety Framework (CSSF)**, as defined by UNISDR.[10] This Framework suggests a series of activities that include:

- Identifying the hazards in and around a school
- Conducting drills
- Preparing contingency and disaster management plans by involving parents, teachers and students
- Building on the capacities of an institution and individuals to cope with the challenges during an unforeseen event

Of the three main pillars of the CSSF, this research is most relevant for pillars 2 and 3. Pillar 1 focuses primarily on infrastructure rather activities linked to teachers and students.

10 https://www.unisdr.org/files/51335_cssbooklet2017updated.pdf



Pillar 2. School Disaster Management: This refers specifically to activities in schools. Key responsibilities under this pillar include:

- Drills on emergency procedures: to practice, critically evaluate, and improve on response preparedness.
- Adopting SOPs (standard operating procedures) for specific hazards, including building evacuation, safe assembly, evacuation to safe haven, shelter-in-place, lockdown, and safe family reunification.
- Adopting SOPs for specific schools.
- Learning safety rules for specific hazards.
- Engaging schools in increasing the effectiveness of early warning and early action systems meaningful and effective.

Some examples of RCRC activities under this pillar include making school safety plans, con-

Why school safety is important in Myanmar

In Myanmar, young people make up around 28% of the population*

8 million + are students

attending **42,000 +** schools

taught by **278,000 +** teachers

The country is vulnerable to frequent natural disasters

- Storms
- Landslides
- Earthquakes
- Floods
- Cyclones
- Drought

Including:

- **May 2008** Cyclone Nargis
- **Jun 2010** Floods in northern Rakhine State
- **Oct 2010** Cyclone Giri
- **Mar 2011** 6.8 Magnitude earthquake in Shan State
- **Oct 2011** Floods in Magway Region
- **Aug 2012** Floods across Myanmar
- **Nov 2012** 6.8 Magnitude earthquake in northern Myanmar
- **Jul-Aug 2015** Floods and landslides in 13 states & regions
- **Jul-Aug 2016** Floods and landslides in six states & regions

When disaster strikes, children and youth are among the most vulnerable. Why?

- Lack of understanding about how to respond
- Limited capacity to cope
- Poor structure of some school buildings

Disasters can result in:

Disrupted education | Psychosocial distress | Long term developmental impacts

For future resilience of families and communities, we need to make **schools safer, children and adults wiser,** and **communities readier** to respond to disaster

* According to the 2014 Myanmar Population and Housing Census. Young people include adolescents (aged 10-19) and youth (aged 15-24).

International Federation of Red Cross and Red Crescent Societies
www.ifrc.org Saving lives, changing minds.

Myanmar Red Cross Society

香港紅十字會
HONG KONG RED CROSS

ducting simulation exercises, creation and capacity building of school disaster committees, first aid training, provision of basic response equipment for schools and training on search and rescue and evacuation.[11]

Pillar 3. Risk Reduction and Resilience Education: This pillar refers to education on risk and resilience issues that goes beyond the confines of schools - i.e. that affect their communities. Key responsibilities of relevance under this pillar include:

- Engaging students and staff in real-life school and community disaster management and first aid activities, including mapping hazards, developing school-based contingency plans, and implementing regular school drills for relevant hazards.
- Developing 'scope and sequence' to detail learning outcomes and competencies to integrate risk reduction and resilience into regular curriculums.
- Integrating risk reduction throughout the curriculum and providing guidelines for integrating risk reduction and resilience into carrier subjects
- Developing teaching and learning materials (for students and teachers)

Some examples of RCRC activities under this pillar include dissemination of awareness raising materials, organization of campaigns and competitions, and awareness sessions as part of the curriculum.

School disaster preparedness and risk reduction activities vary from country to country based on National Society and government capacity and the context of each country. There is no uniform approach, although there are initiatives that have been proposed to present a model for a school-based risk reduction initiative that reflects the pillars and elements of the CSSF[12].

Research has been conducted as to how RCRC NS typically add the most value to school preparedness and the following have been highlighted as key roles and opportunities - all with the potential to build on with immersive technologies:[13]

- Improve knowledge and information management with consideration of **new technologies and innovative approaches** to implement Comprehensive School Safety Framework.
- **Develop teaching materials** and disseminate to schools in line with Public Awareness Public Education (PAPE) Guidelines and its key messages.
- Lead and co-lead **training sessions for school teachers to implement school-based risk reduction.**

Under the umbrella of school safely, SOPs for emergencies and disasters for schools are an essential part of school disaster management policy.[14] These are a set of required safety proce-

11 Myanmar and Philippines Red Cross Societies
12 Such as the handbook for school based risk reduction initiative/model which has been tested in various areas of Asia and provides differential strategies to impact children and youth : http://www.rcrc-resilience-southeastasia.org/wp-content/uploads/2016/02/RCRC-Handbook-for-CSS.pdf
13 These were identified through a variety of consultations in South East Asia: http://www.rcrc-resilience-southeastasia.org/wp-content/uploads/2016/02/RCRC-Handbook-for-CSS.pdf
14 These are outlined in RCRC guidance included in "Public Awareness and Public Education for DRR: https://resourcecentre.savethechildren.net/node/14186/pdf/pape_key_messages_tool_eng_2018.pdf

Figure 2.2: Ten steps of the school-based risk reduction approach for National Societies

Step 1
- Approach a school: Orient the management

Step 2
- Organize basic disaster awareness for teachers and students

Step 3
- Carry out participatory assesments in and around a school

Step 4
- Prepare a school risk reduction plan

Step 5
- Provide special training to school-based risk reduction teams

Step 6
- Carry out simulation exercises

Step 7
- Identify and carry out infrastructure improvements

Step 8
- Engage with parents, local community leaders and the general public

Step 9
- Create links with emergency services of the local government and line departments

Step 10
- Share learning –identify opportunities for scaling up and replicating

dures to be known and followed by all school workers and students, in the event of disasters or emergencies and are built around six basic emergency procedures.

1. Building evacuation
2. Evacuation to a safe haven
3. Assemble and shelter outside
4. Shelter-in-place
5. Lockdown
6. Safe family reunification

These form the basis of the ten steps of SBDRR approach for National Societies (see image).

2.1.2 Audience

School-based preparedness and risk reduction activities target the following:

- Students: a primary audience
- Teachers: an essential vehicle to deliver SBDRR to children, who should also be recipients of training/knowledge
- Parents: Students act as a vehicle to deliver knowledge to their parents. This is often the only source of disaster education in the family.
- Local authorities and community leaders: critical for making community-level decisions on disaster preparedness activities
- RCRC branches and volunteers: School disaster preparedness in National Societies is often led by local branches and volunteers who take part in training-of-trainers courses before passing knowledge to schools

For a breakdown of age related DRR education delivery, see Section 2.2.2.

2.1.3 Key SBDRR activities

The core components and activities of SBDRR that are relevant to the potential for immersive technologies are:

- **Disaster awareness raising activities**
- **Disaster drills/simulations**
- **Training: a)** First aid training and **b)** Disaster management training

These three components of SBDRR are reviewed below. The GDPC has expressed a particular interest in the use of immersive technology for drills and simulations given that the majority of school-based disaster preparedness initiatives such as digital games that have been produced to date have focussed on awareness raising rather than drills or training.

1. Disaster awareness raising activities

Step 2 of the school based risk reduction approach is to *"Organise basic disaster awareness for students and teachers."* Awareness is a key factor in effective risk reduction. Heightened awareness helps to enhance common knowledge of risks, the factors that lead to disasters and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards. Related activities include public awareness and public education and the mainstreaming DRR in school curricula - for example holding education sessions in schools, the use of games, theatre, posters and other media and communications channels and techniques.

This is the area of SBDRR where more creative and interactive participatory measures have traditionally been used to engage students and to improve learning outcomes. For example, a range of digital and non-digital DRR games exist in the Red Cross Movement and beyond to engage students and their families. Some non-digital Red Cross Movement examples include *"Let's Get Prepared"*[15] a DRR Snakes and Ladders Game; *"Escuela Protegida,"*[16] a colouring and activity book for kids on school preparedness; and "Masters of Disaster® Family Kit"[17] containing disaster preparedness games and activities for families. Digital examples include the GDPC's "Monster Guard"; UNISDR's "Stop Disasters"[18] and the US Department of Homeland Security's "Disaster Hero".[19]

15 https://www.dropbox.com/s/0og4g1exre693ut/snake_Eng.jpg
16 https://media.ifrc.org/ifrc/wp-content/uploads/sites/5/2018/12/Libro-de-colorear-escuela-protegida.pdf
17 https://www.redcross.org/take-a-class/preparedness-programs#master
18 http://www.stopdisastersgame.org/stop_disasters/
19 http://www.disasterhero.com

2 Disaster drills/simulations

Drills allow students and staff to prepare for, practice and improve standard emergency response procedures and risk reduction. In some contexts these drills can be the only form of education about disaster response strategies. Drills are a cornerstone of school DRR and preparedness and are proven to be effective, but only if feedback is given to help participants learn and improve. School fire drills have been credited with a significant reduction in fire-related injuries and deaths and large-scale annual drills for earthquakes and other hazards have improved staff knowledge for disaster prevention, preparedness to respond and enhanced disaster policies, plans and procedures. They have also increased staff engagement in disaster planning in their own homes, encouraged them to seek training and reduced their exposure to physical risks.[20] The impact on students is less well documented, and where more of the shortcomings lie (see chapter 3).

School hazard drills and simulations tend to focus on sudden and unpredictable events, such as earthquakes, tsunamis, flash floods, fires, chemical emergencies and more recently in some parts of the world, school shootings. School fire drills have been commonplace since the mid-19th century, mostly centering on evacuation and safe assembly techniques. The standard operating procedures for all of these hazards and events vary substantially and therefore so does the content of the drills. SOPs for other hazards where there is more advance warning do not tend to require the same sudden-onset drill practice, but instead are usually tackled through other awareness raising activities and through teachers or school risk reduction committees ensuring that they have been followed. Drills are used to practice other standard operating procedures as listed above (building evacuation; assemble and shelter outside; shelter-in-place; lockdown; safe family reunification).

20 https://resourcecentre.savethechildren.net/node/14254/pdf/school_drills_r2a_brief_eng_2018.pdf

Simulation drills that are reviewed and assessed allow schools to test and improve their emergency response plans. More recently, mass-participation in community wide earthquake drills has become a popular way to promote disaster preparedness for both organisations and households and this is an area often supported by RCRC National Societies. There is a growing body of research on the extent to which drills contribute to improved individual and organisational safety. For a full literature review of school DRR drills see the Child-Centred Risk Reduction Research-into Action Brief: School Emergency Drills.[21]

It is widely agreed that effective drills should be seen as an experiential learning process and opportunity,[22] and feedback should inform improved techniques and response. Drills begin with advance preparation by staff, providing an opportunity to train students in classroom groups, remember procedures, and check on provisions. The most critical part of the drill process comes after the drill itself, where students can debrief with teachers. This should lead to an evaluation and updated action plan. Research has shown that often this feedback loop is missing after drills, blocking the learning process and putting lives at risk. Other important components of drills including using sample scenarios and injects[23] to add details to a scenario and make simulation drills more realistic; tailoring hazard drills to the most predicted threats and hazards; conducting at least three fire drills per year[24] and at least one full simulation drill to practice for the most common and/or most serious hazards that are predicted to affect the school's area.

3 Training

Training activities in schools for disaster preparedness and risk reduction generally centre around two topics: first aid and disaster management training for staff, volunteers, or school risk reduction teams. First aid training is in most countries one of the core services provided by National Societies and often one of the only entry points to health care or disaster management programming in remote communities. In addition to drills and evacuation training, other disaster management training includes training for staff, volunteers or school risk reduction teams in how to lead an evacuation and disaster SOPs and how to follow them.

The shortcomings of the delivery of these core activities through traditional methods are reviewed in Chapter 3.

21 https://resourcecentre.savethechildren.net/node/14254/pdf/school_drills_r2a_brief_eng_2018.pdf
22 https://resourcecentre.savethechildren.net/node/14186/pdf/pape_key_messages_tool_eng_2018.pdf
23 *Injects refer to new information and challenges that are introduced during the drill, which require thinking and problem-solving, just as would happen in real life.*
24 *The standard advice for schools:* https://resourcecentre.savethechildren.net/node/14186/pdf/pape_key_messages_tool_eng_2018.pdf

2.2 Technology landscape

2.2.1 Immersive technologies available and use

Background

The concept of immersive technologies can be traced back to fiction literature and film, in particular in the genre of science fiction. With the aim of emulating real life experiences that stimulate the human senses and perception, immersive experiences allow users to communicate and interact with digitally designed environments. In the 1960s, cinematographer Morton Heilig developed "Sensorama", one of the earliest known examples of immersive, multi-sensory technology that featured a device integrating a stereoscopic color display, fans, odour emitters, stereo-sound system and a motional chair.[25] During the late 1970s, the main body of immersive technology research was carried out by the military, in particular the US government through NASA. Their main areas of research included computer graphics, networked environments and simulations.[26]

In the 1990s, the gaming industry contributed to the development of immersive technologies and began trialing the first commercial virtual reality headsets including SEGA's VR headset and Nintendo's Virtual Boy. However, the technology was discontinued as it was not able to offer what designers were aiming for. It was only during the 2010s when the first commercial brands were able to build hardware that was powerful and compact enough for personal use. In 2014, social media giant Facebook acquired the virtual reality start-up Oculus[27] and this was the beginning of a new era of immersive technologies made accessible to wider audiences. In the present day, technological advances continue at a rapid rate, providing the affordability of super fast computers and smartphones, which together with fast internet connection mean that the scalability of immersive experiences is finally possible.

Recent research claims this new media will be one of the key mediums of the coming years with an estimated over 200M headsets sold around the world by 2020[28]. However, it is still a very experimental space that is constantly evolving, driven by new technological advances and

25 https://en.wikipedia.org/wiki/Sensorama
26 https://medium.com/e-tech/a-brief-history-of-immersive-technologies-7f98cdcd8aa2
27 https://www.theguardian.com/technology/2014/jul/22/facebook-oculus-rift-acquisition-virtual-reality
28 https://fortune.com/2016/01/21/200-million-vr-headsets-2020/

content experimentation. The entertainment industry is pushing hardware manufacturing and distribution, while software development is also rapidly evolving in the hands of designers and XR developers. This brings an incredible potential for use in the humanitarian sector and, more specifically, in disaster preparedness with the next generation.

Types of XR

For the purpose of this research three main groups of immersive technologies have been identified and presented here.

1. Virtual Reality

Virtual Reality (VR) encompasses immersive experiences and content in most cases using a VR headset, a head-mounted display (HMD) or a fully immersive space. The current reality viewed by the user is replaced with a new computer generated environment in which the user is isolated from the real world. Isolation from the physical location is one of the key attributes of VR as it occludes the user's surroundings. This limits, as well as expands, the possibilities of the technology. When VR works well, it should be seamless and should feel like the physical world. Researchers call this effect "psychological presence", a fundamental attribute of VR, which is the feeling that one is actually in the virtual world.

For presence to be created, VR has to work well. VR author Jeremy Bailenson[29] highlights the technical pillars that need to be executed flawlessly in VR:

1. Tracking and measurement of body movements in the virtual environment.
2. Rendering of the 3D models, objects, sounds and interactions simultaneously while movement is happening.
3. The manner in which the digital world is delivered to the user: the devices, including the headset, haptic devices and speakers.

Another pillar to add to this list is the importance of the experience design, and the effectiveness of the interfaces integrated in the content delivered to the user. Specific recommendations for designing in XR are summarised in Chapters 3 and 4. If any of these aspects are not well aligned, users can experience motion sickness and physical discomfort. But when VR is made with care and with quality, it can be so real that it changes perceptions and behaviours.

VR researchers are experimenting with wearables and haptic technologies which involve touch in order to integrate additional sensory inputs on top of visual and sound content in the experience. For example, haptic controllers in the form of gloves can allow the user to feel the touch of objects, or wearable clothing for sports to control the body for training performance such as full body haptic suits. Others are also experimenting with the sense of smell by adding scents to the experience integrated in a mask which releases scent to immerse users even more in the simulated environment. Recent innovations allow several players to be integrated simultaneously in the same virtual world and this opens a whole new world of opportunities for social and educational uses (see Chapter 4).

29 Bailenson, J, Experience on Demand, 2018

Tesla haptic VR suit for multi-players

Traditionally, virtual reality hardware was costly and clunky. VR researchers required substantial investment to create their own devices by purchasing equipment that could not be transported elsewhere. However, the technology continued to advance thanks to military, business, educational, medical uses such as flight simulators, staff training simulations and medical training. The video games industry has also contributed heavily to the development of both hardware and software. In the last five years, the market has made a swift upwards turn. With the advancements in 3D software, the power of computing, and the development of new portable headsets, virtual reality is finally easier to design as a portable, affordable, quality experience.

In training and learning, VR has been, and continues to be, a game changer.[30] There is research and evidence showing that those trained in VR perform better than control groups who use traditional media in pattern recognition and decision making.[31] In sports, football players are able to reproduce practice in the field. In education, students are able to interact with objects within a 3D environment, or join a virtual reality lecture. Medical students can be trained while watching live-streamed, 3D surgeries from anywhere in the world. Visitors can walk virtually through heritage sites or, visit a virtual museum collection. Humanitarian responders can be immersed in seemingly real-life disaster scenarios.[32] Virtual simulations are increasingly being used across multiple sectors for training and learning in the private sector. For example, VR company Strivr recently worked with Walmart on operations process and procedures to train store managers as well as to evaluate employee performance.[33] The opportunities for training and learning are enormous, and we are only on the cusp of what is yet to be discovered and made possible.

30 Jeremy Bailenson "Practice Made Perfect" chapter, Experience on Demand, 2018
31 Jeremy Bailenson, https://www.youtube.com/watch?v=HZKGde91Xfs
32 https://medium.com/e-tech/a-brief-history-of-immersive-technologies-7f98cdcd8aa2
33 https://www.washingtonpost.com/technology/2019/07/12/walmarts-latest-tool-assessing-whether-employees-deserve-promotion-virtual-reality/?noredirect=on

Types of VR

The current virtual reality spectrum can be classified in several groups. Please refer to the technology review table in Section 3.3 for further details.

- **360 VR (with Smartphone Headset)**: In 360 VR, the content is usually filmed with 360 cameras or created digitally for 360 video. When playing this content through a VR headset, the user is immersed in it and they can look around as if they were inside the space. Interaction features are limited, and include:
  - Looking around the scene
  - Selecting objects by looking at them
  - Shaking the head to trigger interactions
  - Using a separate hand controller to interact with the scene and objects

This technology is usually linked to the use of a smartphone and uses its computing power and graphics capabilities to present the experience. The headsets merely act as viewers. The main challenges of 360 VR today are that content, movement and interaction are limited. However the advantage is that this technology is highly accessible as so many people own smartphones, and it has been integrated into the main video players such as Youtube and Vimeo. In the future, as mobile phones continue advancing, these limitations will likely be overcome.

- **Standalone Full VR:** Standalone headsets contain their own computer, graphics and audio capabilities. They have been developed by companies such as Oculus, HTC, Google, Samsung and others. Main features include all of the 360 VR features plus:
  - Full immersion and transportation in the VR space
  - Use of hand controllers to trigger menus and interactions
  - No computer or smartphone is required
  - Portable and cable free

Image: Oculus Quest

Standalone headsets can have a negative reputation as they come with limited computing capabilities, when compared to VR with computers. However the field of all-in-one headsets is a rapidly growing area and recently a new milestone[34] was reached with the launch of the Oculus Quest in May 2019. This is the first wireless standalone headset with integrated tracking sensors and high quality performance at an affordable price.[35] This opens up the potential for scalability in many areas, especially as feedback received to date has been positive. It is expected that in 2019-2020 one or two more quality standalone headsets will be released and will open up the space of standalone, portable VR. One of the main benefits of these type of headsets is that they require little expertise to set up, and given their cost affordability they could be a good solution for projects that require flexibility and scalability across a range of contexts.

▶ **Full VR with computer:** Computer powered VR headsets are able to provide a high-quality experience for VR users. If the computer offers gaming features such as high computing power and graphics quality, the VR experience can reach very high standards. The headsets manufactured in this set up are connected by cables to the computer and offer high resolution features. The combination of both devices can offer an almost real experience and limited side effects such as motion sickness. These headsets are manufactured by the main tech players including Oculus Rift S, HTC Vive, Samsung Odyssey, Valve Index and others. The resolution on the headset is usually superior than standalone headsets, and some also offer professional features such as quality of displays and increased field of view. As their computing power comes from the PC, the experience can run at high frame rates from 90Hz and above. Main features include:

- Life-like simulations
- High quality graphics
- Ability to explore and walk around spaces
- Full interactivity
- Multiplayer experiences
- Immersive audio

Although these are the highest quality headsets on the market, there are challenges with accessibility of these kits by non-technical users. They are expensive, with the combination of headset and computer usually exceeding 3,000 USD[36] and set-up, use and maintenance of a professional kit usually requires a high degree of technical expertise. These are challenges to consider when planning or scaling a project that would work with any National Societies or other organisations who may not have this expertise.

▶ **Full VR with wearables:** This type of virtual reality aims to enhance the connection of the full body with the virtual world. It uses not only headsets but also other types of haptic wearable devices such as vests, gloves, and full body suits. It is an area under development driven by sports and medical research. Examples include the Tesla haptic suit or Google's upcoming VR footwear.

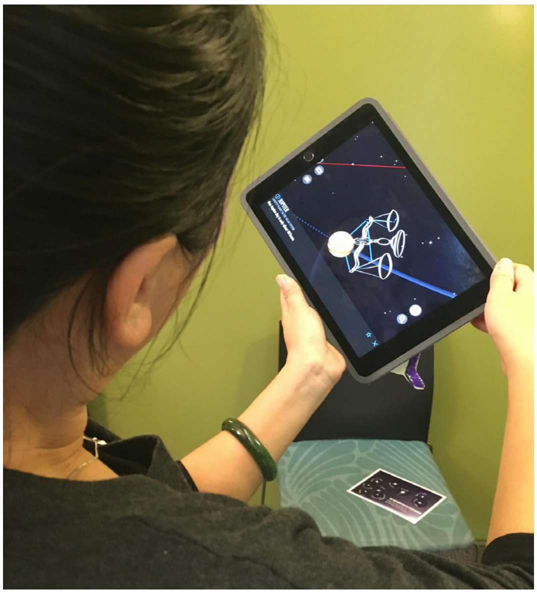
34 https://mashable.com/feature/oculus-quest-vr-review/?europe=true
35 400 USD at the time of writing.
36 Estimated cost of a VR ready gaming laptop and a professional VR headset.

2. *Augmented Reality*
Augmented reality is an immersive technology superimposing layers of digital content onto the physical world to enhance the user's real world experience. Using a device camera and sensors, the technology can analyse the world around the user to reveal layers of computer-generated perceptual information. AR can be experienced by using only a mobile device such as a smart-phone or a tablet. For a more immersive experience, AR can also be viewed with headsets or custom glasses (smart glasses).

One of the key challenges of AR has been to determine how to find points of reference in the physical world that can be used to activate the virtual layers. Mobile devices are not usually equipped with 3D sensors and this has been a major limitation to AR over the past years. The use of markers was required to trigger the experiences. However the new developments in mobile technologies and specific software for AR are advancing rapidly and there are already some devices that include this capability. For example the project Disaster Scope[37] uses a specific AR phone which can 3D scan and analyse the surroundings to create a 3D model of the space as well as locate the phone within it. With the development of mobile devices, cameras, tracking sensors and 3D software these challenges are set to be overcome in the next few years.

Types of AR

- **Marker Based AR:** Uses a marker such as a QR code or an image to trigger the AR scene.
- **Markerless / Location based AR:** Uses the location settings on the user's device to active the AR experience.
- **Superimposition AR:** Uses object recognition to replace an object or several objects in the scene.
- **Projection AR:** Projects digital content onto physical surfaces using a projector.


SkyView app, image Christchurch City Libraries

37 See case study number 9

The strength of AR lies in the fact that components from the virtual world such as graphics, audio, and data blend into the user's reality, altering the view of the physical reality. This means that AR provides an efficient tool for visualisation of content,[38] allowing the development of educational, medical and other applications. AR has seen very interesting uses in the gaming sector such as Pokemon Go, a popular location based game that has been credited for making users discover new locations and help local businesses through footfall.[39] AR has also been applied to innovative medical uses providing benefits for surgical procedures,[40] overlaying interactive content to teach knowledge,[41] or even help children with autism read facial expressions to develop better social skills.[42]

AR has great potential to be used in education and training, engaging students in the learning process as well as helping them improve visualisation skills. One example is the app SkyView which allows users to learn astrology by pointing their phone at the sky or the ground and see where stars, satellites, planets, and constellations are located at that exact moment and receive information about these. The WWF Free Rivers[43] app allows anyone to learn about free flowing rivers in AR and also allows teachers and trainers to explain abstract concepts and help students understand what they are being taught.[44] Although limitations exist with this technology, they are mostly related to technical issues. With the current level of technological growth, this limitation can be overcome in a matter of years.

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38 Singhal, S., Bagga, S., Goyal, P., & Saxena, V. Augmented Chemistry: Interactive Education System. International Journal of Computer Applications, 2012.
39 https://en.wikipedia.org/wiki/Pok%C3%A9mon_Go
40 Chang, Y. J., Chen, C. H., Huang, W. T., & Huang, W. S. Investigating students' perceived satisfaction, behavioral intention, and effectiveness of English learning using augmented reality, 2011
41 Yeom, S. Augmented Reality for Learning Anatomy, 2011
42 https://med.stanford.edu/news/all-news/2018/08/google-glass-helps-kids-with-autism-read-facial-expressions.html
43 Case study number 2
44 Nor Farhah Saidin, Noor Dayana Abd Halim & Noraffandy Yahaya. A Review of Research on Augmented Reality in Education: Advantages and Applications, 2015

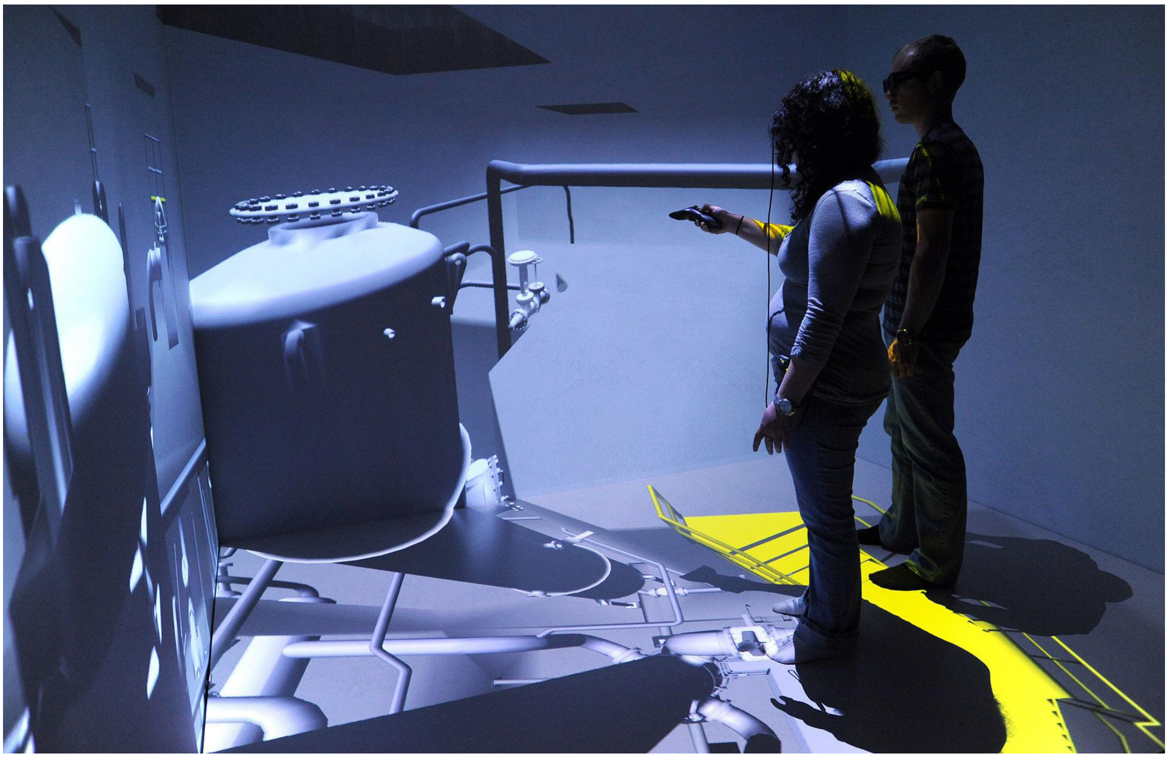
A recent case worth highlighting is the release of Magic Leap in 2018, a spatial computing platform offering a lightweight standalone AR glasses device which is able to seamlessly overlay realistic virtual content over the physical world. The technology used is still being developed and has attracted funding from companies like Google and Alibaba.[45]

Some designers state that AR is set to be - the future of design- as it integrates seamlessly with mobile phones, already an integral part of our lives. As technology becomes further integrated into our lives in less obtrusive ways (à la Google Glass) it is certain that augmented reality will provide opportunities to enhance user experiences beyond measure.

3. *Extended Reality*
Extended reality (XR), also known as cross-reality and hyper-reality, is an umbrella term that encompasses human-machine interactions generated by computer technology with devices or wearables to create real and virtual environments which include VR, AR and in this research paper also encompasses mixed reality as part of XR. Mixed reality (MR) is a hybrid definition combining both AR and VR. Recently released MR devices such as Microsoft's Hololens and the Magic Leap demonstrate what mixed reality can do by allowing users to interact with holographic augmentations in a seamless manner.

The ultimate aim of XR is to seamlessly integrate the virtual and physical worlds to create new and enhanced experiences. This requires the integration of several technologies, including mixed reality, which refers to the combination of both VR and AR.

▶ **Immersive spaces:** VR in space with headset, computer and projections.
Immersive experiences take over a dedicated space, such as a purpose built room or a media



45 https://www.techradar.com/news/magic-leap-one

room. These spaces allow for the use of VR, AR or mixed reality headsets, along with other media to blend the virtual world, for example: projections, displays and external audio.

One example is the CAVE system (cave automatic virtual environment), a room with projection screens as walls, where high resolution and stereoscopic projectors display realistic 3-D computer graphics, creating an immersive user experience.[46] This system allows multiple users to be in the same space.

Innovations in the use of immersive spaces continue to appear in the arts and entertainment sector, with artists pushing the boundaries of perception and space. For example, the work of Japanese technology studio teamLab[47] transforms large gallery spaces into full-body immersive art experiences in which users can explore dreamlike worlds evoking nature and technology. Their exhibitions present interconnected spaces which react with visitors and between each other.

Borderless by Teamlab at Mori Museum, Tokyo

UK based art studio Marshmallow Laser Feast recently created an experience at London's Saatchi Gallery called "We Live in An Ocean of Air" to explore our connection with the natural world. In this experience, participants were able to walk around and explore the VR environment, and also interact with it using their breath, pulse and even using their hands instead of controllers.

46 NYU https://wp.nyu.edu/aimlab/resources_main/cave/
47 https://www.teamlab.art/

We Live in An Ocean of Air by Marshmallow Laser Feast at the Saatchi Gallery, London

Another innovative use of immersive mixed reality and AR is The Weather Channel Segments. These short segments used when there is a threat of flooding show the viewer what it would be like to be in the middle of the flood if water levels were to rise as predicted. They are built in an immersive mixed reality environment, a step up from AR in which, instead of projecting small objects in front of presenters on-air, the entire space around the presenter can be transformed into a virtual environment powered by games engine Unreal. The maps and data are presented in real time and the weather conditions driven by forecasts.

While immersive spaces can provide state-of-the-art immersive experiences, they require a great amount of resources to install, run and maintain as the technologies used and the level of expertise required is very high. One benefit they offer is that they can be set up as permanent or semi-permanent spaces where research can be centralised and multiple experiences can be presented to different audiences at the same level of quality.

2.2.2 Usage and age restriction guidelines

Players and Avatars

One of the powers of new XR technologies is to place the user at the centre of the experience and to enable them to make their own decisions. Experiences can be designed integrating different perspectives and points of view including:

- First person view actor: the experience is viewed as if the user was looking through their own eyes, and they make decisions about how to interact with the experience. They are the main characters and they are responsible for their actions. This view is typical of games and full VR experiences that allow interaction.
- First person view observer: the experience is viewed in first person. The user is not able to make decisions about the main narrative, but can explore it. This is typical of 360 video.
- Third person view: the user can view and control the main character, usually represented by an avatar.

With the development of new experiences that allow multiple players, it is expected that new points of view will be developed. Preceded by virtual platforms like Second Life, in "social VR" participants can get together in the virtual space and interact with each other, as avatars. This is considered to be one of XR's next milestones.[48]

Another consideration is the integration of the "narrator" or "guide". This is a common technique used in games and educational experiences to allow the user to navigate the experience. In the context of XR, it can be very effective to integrate a guide to direct the narrative of the experience, delivering key messages as well as connecting the user with the experience through empathy. The recently launched Star Wars - Vader Immortal game for Oculus Quest features a droid copilot that acts as a guide, reminding the user of actions that need to be completed.

Vader Immortal: A Star Wars VR Series – Episode I

48 See Chapter 4.

In games, such as 1979 Revolution: Black Friday,[49] the main character receives guidance and support from other characters involved in the game, such as friends and family. In Lifesaver VR,[50] the narrator is a voice over guiding the experience and is timed with interactions on screen. Non-character driven experiences can also provide guidance through in-experience menus, warnings and alerts. For example in WWF Free Rivers[51] bubble menus appear to guide users through the experience.

Health and safety

The effect of XR technologies in the long term is not yet fully understood as the technologies are so new. Moderation is recommended for all users and particularly for children. Instead of hours of use, which can apply to other screens, it is recommended to think in terms of minutes. If the experience is AR on screen, use time can be increased, but most VR experiences are not recommended to exceed five to ten minutes for children.[52]For adults, it is recommended to take breaks approximately every 20 minutes.

VR and other immersive experiences, in particular those using headsets, also come with the extra challenge of sickness and discomfort. To minimise the risk of motion sickness, time should be limited and XR experiences should not be scheduled during the last lesson of the day to ensure student safety after leaving school.[53] The Oculus store grades experience comfort levels however there is no defined standard in other stores. Features such as vignetting, which reduces the field of view during movement, or teleportation allow the user to move around without discomfort. By definition, VR blocks out the real world so it is key to define a safe space to play, free of sharp edges, pets, walls or other obstacles and dangers.

More recommendations on health and safety can be found in the devices' health and safety warning instructions, such as the Oculus VR warning notes, the Microsoft Mixed Reality notes or ClassVR who offer an updated VR health and safety guide on their website. Any safety warnings developed should include notes about how to use headsets, how to set up a safe space, what are the common risks associated with XR and what to do in case of discomfort. It is recommended to print a summary of health and safety warnings and ensure all users read it before they start the experience.

It is also recommended to create an onboarding time for each user once they are immersed in the XR experience, especially for those that have never experienced XR technologies before. This is particularly important to consider in the case of fully immersive VR experiences. Onboarding should include usage notes, menu instructions as well as instructions for how to end the experience in case of physical discomfort.

49 *Case study 8*
50 *Case study 5*
51 *Case study 2*
52 *Jeremy Bailenson in Aubrey, J. S., Robb, M. B., Bailey, J., & Bailenson, J. Virtual Reality 101: What You Need to Know About Kids and VR. San Francisco, CA, 2018*
53 *Handbook for a School-based Risk Reduction Initiative by IFRC*
http://www.rcrc-resilience-southeastasia.org/wp-content/uploads/2016/02/RCRC-Handbook-for-CSS.pdf

Privacy & Security

XR technologies raise many issues around user privacy and security and many of these questions are still unanswered. Security and privacy risks have been raised concerning the access and use of user data by third party agents and particularly on user data gathered from wearables and mobile devices. For data protection, there is a lengthy list of properties that need to be addressed such as integrity, availability, confidentiality, unlinkability, anonymity and pseudonymity and plausible deniability.[54] Since most of the VR hardware and software providers have privacy policies available on their websites it is strongly recommended to carefully review these policies and act on them.

Recommended points to consider include:

- Review data gathered and inputted into the XR platform, as it might include sensitive information that needs to be protected.
- Any data collected, processed and stored in any XR application has to be reviewed. Making data public without the end user's consent, for example sharing it within a platform provided by the hardware or software manufacturer might break privacy rules. This is especially important when organising XR events as the organisers control the hardware and software however users do not have the time to choose their privacy preferences. A best practice for event organisers is to disable all possible sharing options from the device settings.
- Sharing data with third parties may include sensitive information and it would have to be reviewed. However where possible this option should be disabled.
- Tracking data for user testing while developing an application should be another point of concern for XR developers. The best practice is to maintain anonymous tracking and to avoid collecting any personal identifiable information from the user.

Age Recommendations

Any new technology should be considered with care and moderation, especially with anyone under age. New technologies bring fundamental changes to the lives of 21st century children who are the most frequent users of emerging digital and online services[55] such as YouTube or Instagram. However not every child benefits equally from online opportunities.

Children and young people are also avid users of video games and are increasingly aware of VR and XR experiences, however there is not yet an official standard body such as PEGI ratings[56] generating guidelines for different technologies and age groups.

The age of seven is a critical point, as it is typically the age by which children understand the plausibility of media events.[57] Thirteen is the age recommendation of full VR headsets stated by

54 *Security and Privacy Approaches in Mixed Reality: A Literature Survey* *https://arxiv.org/pdf/1802.05797.pdf*
55 *OECD, New technologies and 21st century children: Recent trends and outcomes OECD Education Working Paper No. 179, 2016*
56 *https://pegi.info/*
57 *Claxton, Laura J.; Ponto, Katelyn C. Understanding the Properties of Interactive Televised Characters, 2013 and Woolley, J and Maliki E. Revisiting the fantasy-reality distinction: children as naïve skeptics, 2013*

their manufacturers (HTC Vive, Oculus Rift S, Oculus Quest and others). Oculus' CEO explains the age limit chosen:

"It's early days and we really are trying to be conscious of health and safety".[58]

VR author Jeremy Bailenson also supports a similar message:

"Until research yields more clues on the effects of VR on children, common sense should prevail."

Recent research on children and virtual reality focuses on children aged eight - 12[59] and investigates if there are any potential harmful effects of experiencing VR under 13. Some of the conclusions outlined in the report include:

- All children asked to play for longer.
- They used VR in very social ways, for example simultaneously talking to their friend outside the experience.
- Children seemed to prefer low poly or cartoon graphics, such as Job Simulator (pictured below). This allowed them to bring their own narratives into the experience.
- Recommended frames per second were 60 fps, and any below 30 fps was disorientating.
- Children's engagement was multisensory and they played with their whole bodies.
- They enjoyed breaking the rules and doing things they couldn't do in the real world, such as setting things on fire.

Job Simulator Screenshot

58 chttps://www.vrfocus.com/2015/06/oculus-rift-age-limit/
59 *Children and Virtual Reality, Emerging Possibilities and Challenges, 2017*

In the case of AR, the impact has to be assessed differently to VR as the content can be viewed on screen based devices, rather than headsets. This allows technology recommendations to be more aligned with content recommendations.

Aside from the technology, one important aspect to consider is the nature of the content and how it might influence or even traumatise children. A good content rule is, if you would not want children to live with the memory of the event in the real world, then do not have them do it in XR. Read more about Content Design and recommendations in Section 4.2.
Below is a summary of recommendations per age group.

Age	Tech	Content	Notes
0-3	No tech or screen based activities recommended at this age[1]	No tech or screen based activities recommended at this age	No tech or screen based activities recommended at this age
3-6	Screen based experiences (mobile, tablet, computer or gaming console)	Gaming, fantasy	Short time periods, under 5 mins
7-9	Under adult supervision - screen based experiences, AR and 360 VR experiences	Gaming, fantasy, low shocking realistic simulationsvv	Concrete operational cognitive development - age from 7 years old - short periods (5-7 mins)
9-12	Under adult supervision - screen based experiences, AR and 360 VR experiences	Gaming, fantasy, middle shock realistic simulations	Concrete operational cognitive development short periods (5-10 mins)
13-17	Under adult supervision. Full interactive VR, immersive spaces	Gaming, fantasy, middle shock realistic simulations	Formal operational cognitive development. Breaks every 10-15 mins
+18	Full interactive VR, immersive spaces	Gaming, fantasy, shocking realistic simulations	Adult - All content is allowed too. Breaks every 20-30 mins

2.3 History of XR in disaster preparedness and risk reduction

Since the 1970s, new technologies have been used to create simulations that bring disasters to life through computer visualisations and game environments. Different lines of work have advanced this niche, including scientists who create computer simulations to analyse natural phenomena and military defence bodies who worked to develop training systems for emergency responders. In 1992, the Advanced Disaster Management Simulator (ADMS) was introduced in response to a plane crash at the Manchester Airport (UK) to train incident commanders in a real-time interactive virtual reality environment, which was built as a game simulation and was explored using computer monitors and joysticks. This tool still exists and is being used by several national bodies around the world including the New York City Office of Emergency Management.[60]

60 https://en.wikipedia.org/wiki/Advanced_disaster_management_simulator

ADMS on WPIX Channel (date unknown)

Before XR technologies became more widely accessible, DP/DRR training and simulations were offered through screen based devices such as computers, monitors or gaming consoles. In the last decade serious games (SGs) have become popular training and behavioural analysis tools and examples are present across industries, for example:

- The oil industry[61]
- Terrorist attacks[62]
- Fire evacuation[63]
- Earthquake evacuation[64]
- General disaster evacuation[65]

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61 For example in Mayer, I., Wolff, A., & Wenzler, I. (2013, September). Learning efficacy of the 'hazard recognition' serious game. Serious Games Development and Applications, 118-129; and Metello, M.G., Casanova, M.A., & Carvalho, M.T.M. (2008, December). Using Serious Game Techniques to Simulate Emergency Situations. GeoInfo, 121-182.
62 For example: Chittaro, L., & Sioni, R. (2015). Serious games for emergency preparedness: Evaluation of an interactive vs. a non-interactive simulation of a terror attack. Computers in Human Behavior, 50, 508-519.
63 For example: Smith, S., & Ericson, E. (2009). Using immersive game-based virtual reality to teach fire-safety skills to children. Virtual Reality, 13(2), 87-99.
64 For example: Tanes, Z., & Cho, H. (2013). Goal setting outcomes: Examining the role of goal interaction in influencing the experience and learning outcomes of video game play for earthquake preparedness. Computers in Human Behavior, 29(3), 858-869.
65 Cohen, D., Sevdalis, N., Taylor, D., Kerr, K., Heys, M., Willett, K., Batrick, N., & Darzi, A. (2012). Emergency preparedness in the 21st century: Training and preparation modules in virtual environments. Resuscitation, 84(1), 78-84.

Many of these screen-based simulations are available online as websites or mobile applications on the Google and Apple Stores. Examples include: *Stop Disasters Game* by UNDRR, available online, provides game simulations for up to five hazards; *Humanitarian Hero* by American Red Cross, a game that embarks users in several missions with the aim to become a humanitarian hero and *Tanah: The Tsunami and Earthquake Fighter* by the GDPC, a disaster preparedness educational mobile app designed for kids and families. Alongside these specific applications and websites, there is a world of video content which has been used for DRR education, some of it available on online platforms such as YouTube.

The DRR community is actively engaged in researching and testing innovative XR ideas. The main change seen from the use of XR technologies is the possibility to fully immerse the user inside the simulation, which opens new avenues for DRR training, especially in the field of simulations and drills. 360 video (both in VR format or for web) has been widely used to build empathy and generate engagement. The successful use of virtual reality simulations in disaster management training initiatives is a popular area for research, particularly building evacuations for fire and earthquake, and has proven to influence behaviour and learning outcomes. On the horizon is the research focused on augmented reality as a new medium for training disaster preparedness with location specific features which allows targeting the experience to any given location, with clear benefits for scalability.

Another important addition to XR today is the integration of digital serious games as part of XR experiences, offering a unique combination which can produce behavioural and pedagogical outcomes. This is still an emerging field in which researchers and creators are testing experimental new ways to engage users more and find new innovative ways to transmit knowledge using a variety of practices.

All of these developments and opportunities for SBDRR are considered in Chapters 3 and 4.

#3
Analysis

Introduction

This chapter presents a gap analysis of the limitations of traditional SBDRR activities and the potential solutions that XR provides to address these limitations. Learnings and recommendations on the design, production and delivery of XR experiences specific to the Red Cross Movement are presented at the end of this chapter, to build on the technological affordances for specific SBDRR activities. It is important to note that XR should not replace traditional teaching methods, in particular methods that are proven to work. Any use of technology must not recreate education as it already is, but utilise the unique advantages of the technology to bring added value to what is already in practice with other learning modalities, targeting shortcomings and providing solutions where the technology is accessible, scalable and affordable.

3.1 Gap analysis of SBDRR limitations & XR opportunities

Many traditional SBDRR methods of delivery are effective in conveying disaster knowledge and raising awareness of disaster management for children and adults. There are however a range of identified shortcomings in traditional methods of delivery and learning. The challenge of the main SBDRR activities - training, drills/simulations and awareness raising - often lies in conveying knowledge in an engaging and effective manner that can change behaviour while allowing for contextualisation and dissemination at a wide scale.

XR technologies have the potential to change teaching methodologies and overall reach, supplementing the already established practices and procedures applied in schools. Research has found that XR, for example VR and serious games for building evacuations, employ novel and effective techniques to overcome the limitations of traditional approaches. For example, VR technologies have proven valuable in investigating behaviours in fire evacuation, such as system perception, pre-movement behaviour, wayfinding, exit choice and navigation interactions.[66] This emerging technology allows users to be exposed to more realistic evacuation scenarios by representing several threats concurrently.

This section presents a gap analysis of the limitations of traditional SBDRR activities and the potential solutions that XR provides to address these gaps. The shortcomings are classified by the main SBDRR activities outlined in Chapter 2: 1) Disaster awareness raising activities; 2)

66 These are documented in literature reviews and case studies including the Auckland City Hospital case study and literature review.

Disaster drills and evacuations; and 3) Training (first aid and disaster management). In reality there is overlap between these activities - for example drills are a form of disaster management training and are also an awareness raising activity. However because they are often conducted as separate activities, and to allow for the analysis, they are presented here in three categories.

3.1.1 Disaster awareness raising activities

In activities that focus on disaster awareness raising, the main goal is that students develop knowledge, understanding and skills on disaster management. This is the SBDRR activity where there has been the most creativity shown to date in harnessing technologies to increase learning outcomes, including mobile phone apps and digital games. However the bulk of SBDRR awareness raising activities are still conducted in a unidirectional, non-participatory manner. Students are often the passive recipients of information, leading to low levels of motivation, knowledge retention and understanding of real hazard effects. XR technologies have the ability to motivate students and improve learning outcomes and knowledge retention due to the "wow factor" they still hold and their ability to visually represent what is often delivered by verbal or written methods.

Some of the shortcomings of this activity are presented below, alongside the opportunities that XR technologies offer to address and fill these gaps.

Participation and Motivation

*Often students are **passive recipients of information** rather than being actively engaged in the awareness raising activity. They **lack participation** and **motivation** due to methods of delivery with low engagement, that can also be outdated or monotonous.*

<u>XR Opportunities</u>

XR experiences increase student engagement and motivation. This benefit is applicable to all new XR technologies. AR and VR still have the "wow" factor and the ability to motivate participation. For example, research has found that tablet-enabled AR used in school learning is 1) able to prove a positive increase in student engagement and 2) increase student motivation towards learning.[67] User's increased enthusiasm is noted in the case study of ZIKA360[68] where students were highly engaged during the duration of the activity and actively participated.

Learning by doing - whether with immersive or gaming technologies - is naturally more participatory than passive information receiving. Moreover, studies have shown that **users' behavior can change** when using VR, making them feel more personally accountable or responsible for the action in each scene. This transforms into higher degree of participation and engagement

67 Hibberd, R, A Johnson, D To and S Vora-Patel, Engaging the 21st century learner: Using augmented reality to increase student engagement and student achievement in an inquiry-based learning environment, 2012
68 ZIKA360 Case Study Number 1

in the activity. For example, immersive VR is proven to enhance the enthusiasm of children for fire-safety skills training by improving their engagement with the learning environment.[69]

VR is an extremely powerful motivational tool. Game-based VR systems increase children's motivation over more traditional teacher–learner forms of VR-based instruction. **Digital game-based learning**, when used appropriately, can provide students and educators with better attitudes towards learning, increase student motivation, foster higher-order thinking, influence personal real-life perceptions, impacts decision-making processes, and aide students learning achievements.[70]

Participation and motivation can also be integrated in the process of designing and building an experience. In the case of VR Action Lab[71], the design process increased participation by involving members of the target audience group in making the experience. The user-centered approach with people and not for people involved in the particular issue (bullying) allowed the creators to engage more young people in the process and to achieve better results. In the case of Disaster Preparedness Simulator,[72] the user-centered design process involving not only teachers and students but also local authorities in the Philippines increased awareness of the project and participation and motivation of all the actors involved, with benefits for the uptake of the tool.

Knowledge Acquisition, Retention and Application

It is **difficult to apply knowledge gained through traditional educational methods** *to real life contexts*. According to research presented by Dunleavy & Dede,[73] *"Even students who excel in educational settings often are unable to apply what they have learned to similar real-world contexts."* This is even more the case in disaster education, where concepts can be very abstract if not experienced previously in real life.

XR Opportunities:

Immersive technologies, with their emphasis on "learning by doing" can address this shortcoming through providing knowledge through a medium that makes the user feel they have experienced the event in real life, making it easier to retain and apply knowledge learned. This advantage is explained in research on educational communications and technology:

"The potential advantage of immersive interfaces for situated learning is that their simulation of real-world problems and contexts means that students must attain only near-transfer to achieve preparation for future learning.

69 Smith, S., & Ericson, E. (2009). *Using immersive game-based virtual reality to teach fire-safety skills to children. Virtual Reality, 13(2), 87-99.*
70 *Von Gillern, S., Alaswa, Z. Games and Game-based Learning in Instructional Design, 2017*
71 *VR Action Lab by Harmony Labs, Case Study Number 3*
72 *Disaster Preparedness Simulator by Ania Design Labs. Case study Number 9*
73 *2014, p. 737*

Flight and surgical simulators demonstrate near-transfer of psychomotor skills from digital simulations to real-world settings; research on the extent to which AR can foster transfer is an important frontier for the field."[74]

For example, in the case of sports training, VR expert Jeremy Bailenson explains how he worked with a student to create a VR simulation to train football players, using 360 footage so that,

"real footage would help create the sense of presence, the sensation of "being there" in the virtual space, that was crucial to the learning experience we were creating."[75]

Recorded footage of the training sessions allowed players to repeat scenes as many times as required to study the game in detail. The VR training was implemented in 2014 and as a result the team's total offense improved from 24 points per game to 38 points per game during this same period.

AR combined with gamification can lead to increased knowledge acquisition and retention. When combined with gaming techniques, AR experiences have shown positive impacts on learning, reinforcing existing learning and gaining new knowledge, and on behaviour change for disaster or health education. Using gamification has also shown motivation to obtain a high score, thereby increasing engagement. Students playing the Zika360[76] AR app were interested in the app and in taking the quiz, which tested student knowledge acquired during the experience and provided a score. Most of the students obtained very high scores and those who did not, subsequently asked to repeat the quiz. This shows that the tool was effectively designed to validate and reinforce the key messages that the project aimed to deliver.

Using game mechanics such as conversation trees can be useful **to instill knowledge whilst maintaining high engagement.** This is shown in the 1979 Revolution[77] game, which includes a branching storyline in which the user is the main decision maker and driver of the narrative.

Visualisation & Visual Representation

The combination of visualisation and representation of concepts and situations contributes to improved cognition. However in traditional forms of DRR education, there is a **lack of understanding of real hazard effects due to a lack of visual representation of hazards** - for example of what water levels rising in a flood would actually look like. This naturally leads to a difficulty understanding and visualising the impacts of a disaster.

74 Spector, M, David Merrill, Jan Elen, M. J. Bishop, Handbook of Research on Educational Communications and Technology, 2013
75 Bailenson, J, Experience on Demand, 2018
76 Case study number 1
77 1979 Revolution Black Friday, Case Study number 8

XR Opportunities

XR contributes to improving visualisation of "hard to visualise" concepts that can not be normally seen in the real world, including hazards. XR can overcome this barrier because it has the potential to visually represent the hazards and their impacts, whether in immersive VR, or headset/mobile AR. AR can effectively make visible concepts that may be hard to explain and research has demonstrated the beneficial use of AR technology as a means of visualising concepts. For example, the *Disaster Scope* AR app[78] can effectively visualise fire smoke in an indoor space and allow participants to understand the escape route, also contributing to the learning of spatial skills. *The Weather Channel* uses immersive mixed reality to show the viewer what it would be like to be in the middle of the flood if water levels were to rise as predicted, to motivate people to evacuate their homes in times of high flood risk.

Visualisation of hazards leads to increased understanding of what experiencing the hazard would be like, activating the memory of a visual representation of the hazard, which in turn motivates behaviour change and increases knowledge retention. In WWF's *Free Rivers*,[79] the AR visualisation allows users to understanding a complicated topic of rivers, dams and flooding, with high quality graphics, accurately designed people, plants, ecosystems and animals, and clear, vivid visuals which have a positive effect on teaching about a subject that is otherwise hard to visualise, or that can be perceived as not engaging.

3.1.2 Disaster drills and evacuations

> *"From a pedagogical point of view, it is difficult to ensure that [traditional] evacuation drills provide effective training. In fact, evacuation drill participants often receive no feedback whatsoever to help them assess their evacuation choices retrospectively."*[80]

Drills and evacuation simulations aim to empower people to act and survive in case of disaster, for example by practicing how to physically evacuate a school in an emergency. Approaches such as videos, posters, seminars, courses, or evacuation drills are used in evacuation training. However there is little post-disaster research on the effectiveness of school drills and their role in the prevention of injuries and deaths. One exception is research by Save the Children into school drills and how to make them more effective.[81] *This study concludes that "while drills may provide important and necessary learning opportunities, it is not clear whether they improve children's situational awareness and decision-making skills. Researchers recommend improved situational awareness, mastery of response skills, realistic simulation scenarios, practice in decision-making, increased school*

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78 Case study number 9

79 Case study number 2

80 Lovreglio, R, Gonzalez, V., Feng, Z., Amor, R., Spearpoint, M., Thomas, J., Trotter, M., Sacks, R., Prototyping virtual reality serious games for building earthquake preparedness: The Auckland City Hospital case study, 2018

81 Johnson, Victoria A., Towers, Briony, Petal, Marla, Child-Centred Risk Reduction Research-intoAction Brief: School Emergency Drills, for the Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector, 2018 *accountability self-assessments, and 'after-action reviews' to stimulate improvements in school disaster management."*

There is great potential for XR to address some of these recommendations and particularly the main limitation of evacuation drills: the difference between the real-world emergency and the simulated emergency, a major barrier to participant learning. It is essential that drills provide opportunities for children and teachers to apply their knowledge to a range of scenarios, be put to the test with problem solving and unexpected scenarios and then give and receive feedback on how they responded. XR is of particular relevance to improving disaster drills and evacuations given the number, types and nature of shortcomings of traditional methods that make it difficult to gain real mastery of response skills. These are listed below, with the potential of XR to address them.

Realistic Disaster Simulations
Traditional SBDRR cannot provide realistic simulation scenarios. The main limitation of evacuation drills is the difference between the real-world emergency and the simulated emergency, which can seriously prevent participants' learning.

XR Opportunities

> *"A VR experience is often better understood not as a media experience, but as an actual experience, with the attendant results for our behavior."*
> **Jeremy Bailenson, Experience on Demand**

XR can **simulate a disaster** either in a virtual, augmented or mixed reality environment in realistic ways that make the user feel like they have actually experienced it. The hazards that are most experimented on with XR to date are fire and earthquake, as they have the least warning and are the most likely to require rapid building evacuation. One of the key challenges is to develop disaster scenarios that are realistic but not overly frightening for students. Research has found that well-planned drills and associated learning activities do not increase anxiety or worry in children; rather, they increase their knowledge of what to do and their confidence in their coping abilities.[82] The method used will depend on the age group targeted and recommended age restrictions. Acquisition of response skills and drill practice should be modified for different age levels and abilities and should leverage children's unique strengths and capabilities.[83] For learnings on designing simulations with the appropriate realism/fear balance to promote action but not overwhelm, see Section 3.2.1.

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82 *Johnson, V., R.Ronan, K., Johnston, D., Peace, R., Evaluations of disaster education programs for children: A methodological review, 2014*
83 *For a full list of pointers per age group, see p. 5 onwards in the following paper: Johnson, Victoria A., Towers, Briony, Petal, Marla, Child-Centred Risk Reduction Research-intoAction Brief: School Emergency Drills, for the Global Alliance for Disaster Risk Reduction and Resilience in the Education Sector, 2018*

A huge advantage of XR technologies is that they can be used to train for potentially dangerous situations that are hard to recreate in the real world, through this recreation of realistic disaster simulations. VR is being used by companies in the private sector to train employees to learn how to cope with potentially dangerous situations that are difficult to train for in in real life, for example Verizon is using VR to train staff on how to act in case of robbery. AR can also be used to train on dangerous topics, for example by bringing to life floods or fire as shown in *Disaster Scope*.[84]

XR can test a wide range of varied and realistic scenarios including:

1. Scenarios from real footage, such as from 360 video in VR. In this case the scenario is exactly like reality and provides real references of the physical world. This can be effective to portray characters. For example in *VR Action Lab,* the creators wanted to show real young people in the experiences so that users, who were also young people, could empathise with them. In the case of *LifeSaver VR*, the characters are also real from 360 footage, with the aim to create an emotional connection with the target audience. The British Red Cross' 360 First Aid Bystander Effect VR experience, 360 video allows the viewer to feel like they are in the train where the first aid emergency takes place.

2. Scenarios created in 3D with computer graphics and 3D software. The type of graphics can vary from cartoon-like to hyper-realistic 3D. These graphics are computer generated and allow for more control of the assets and customisation without having to redo full scenes. For example, the ICRC VR team create experiences simulating conflict zones and areas of their work such as a prison-based simulation for detention delegates. By examining a realistic scenario, delegates learn to assess detention conditions as well as to speak to prisoners. These simulations are created using advanced 3D graphics and built using video game engines to offer maximum control. ICRC opted for 3D graphics rather than 360 video to make the simulations generic in appearance and therefore more applicable to multiple contexts or countries where they work. FEMA's Immersed, Ania Design Lab's Disaster Preparedness Simulator and APDRC's VR for resilience fire and cruise ship simulations all use 3D graphics to deliver the experiences.[85]

One of the main benefits of working with 3D graphics is the possibility to create libraries of assets, which can be reused in different experiences, making the system more scalable and more cost effective in the long term, particularly if shared across the RCRC Movement or humanitarian sector.

Situational Awareness
Traditional drills do not incorporate **situational awareness learning:** Traditional drills do not allow children to learn situational awareness, the perception of environmental elements and the comprehension of their meaning.

84 *Case study number 9*
85 *See case studies numbers 10, 6 and 7*

XR Opportunities

XR can create a realistic environment to show the scope of a disaster in the actual location where the training is happening, such as in a school. For example, the Disaster Scope[86] AR app reveals how floods would affect students by allowing students to be immersed in a flood situation in their school. By showing the water height students can understand which areas of their school and the surroundings could potentially be safe or unsafe during floods.

There are three key aspects of situational awareness in which XR technologies can be effective:

1. Prepare: How to prepare for a disaster.
2. Respond: Acquire decision making skills and learn how to act during a disaster.
3. Recover. Learn how to act after a disaster.

In FEMA's Immersed 2.0, the experience challenges homeowners to make decisions for themselves in a flood and see the impacts their decisions and consequences of inaction have across the whole neighbourhood. For example, how to ensure you can still commute in a flood or pick the kids up from school. The Zika360 AR app shows a representation of the community and the common areas where preparedness must be implemented, including in school, at home and in a medical centre.

Feedback & Evaluation

In many traditional drills, there is little integration of feedback or monitoring and evaluation mechanisms. Drills as they are usually conducted in SBDRR often do not provide feedback to participants help evaluate and assess choices made and to improve performance. Those in charge of drills often focus on improving the speed of the drill, rather than looking at how to improve technique, for which feedback on performance is critical. Feedback should improve both the process and the participation for students and teachers, but this is rarely the case. This shortcoming is highlighted in a comprehensive literature review of evacuation drills that states that, *"From a pedagogical point of view, it is difficult to ensure that evacuation drills provide effective training. In fact, evacuation drill participants often receive no feedback whatsoever to help them assess their evacuation choices retrospectively."*[87] This is one of the greatest shortcomings of traditional drills and one of the most significant opportunities for XR.

XR Opportunities

XR can provide feedback to users both in the experience, for example on choices made within a VR simulation, and out of experience, for example in a classroom setting afterwards and/or as part of a broader training package. The technology can also provide feedback to the developer, owner or instructor (for example the teacher), including on analytics and analysis of behaviour patterns. Some examples[88] of in-experience feedback can include:

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86 Case study number 9
87 Lovreglio, R, Gonzalez, V., Feng, Z., Amor, R., Spearpoint, M., Thomas, J., Trotter, M., Sacks, R., Prototyping virtual reality serious games for building earthquake preparedness: The Auckland City Hospital case study, 2018
88 ibid

- A life bar showing the health of the virtual user/player in the experience to highlight the severity of the consequence of any unsafe actions taken.
- A cause of "death" message (i.e. an in-game text message indicates why the users lost their life) and a behavioural recommendation. Note: Levels of realism should be weighed with ethical considerations in countries where a portion of the population has been affected by major disasters or with young children, which may preclude their use in favour of lower fidelity options.
- Use of 'knowledge points' for correct decisions, and the loss of points or time penalties for incorrect decisions.[89]
- Immediate and formative user feedback about performance at each decision level[90]
- Taking users back to the point where they made a wrong decision and allowing them to restart from that point.[91]
- Including a quiz in the experience that can act as a tool for testing and receiving feedback from users and provide an effective way to understand if the user has achieved the desired learning goals.[92]

Some examples of out of experience feedback include:

- Integrating the experience into a training package so that is is not standalone and where users are provided feedback after the experience.[93]
- Screening the experience being used live so that other students/teachers can join in the feedback discussion and make one person's experience more participatory.
- Providing feedback at the end of the experience tailored to each user, for example through a list of correct and incorrect actions based on national guidelines or school SOPs and how users can improve for next time.[94]

XR has the potential to give more detailed and tailored feedback without a huge increase in human resources to observe the drills in real time. Feedback can be used to improve both the process and participation and go beyond focusing on the speed and efficiency of the drills. This feedback can come from other students who are, for example, watching the XR simulation on a screen, or via a multiplayer experience.

XR can also enable investigation of user behaviour, particularly linked to decision making. For example, simulating earthquake damage in a virtual environment can allow the assessment of users' reactions to different evacuation conditions, acting as a "virtual laboratory" with greater experimental control than traditional drills.[95]

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89 This is a technique used in the app LifeSaver VR, which provides instant feedback on the user's handling of CPR tests by showing a score.
90 For example in Lifesaver VR when the user is told if they are applying chest compression rates at the appropriate speed.
91 This is the approach used in Lifesaver VR when CPR compressions are not done correctly. This technique is used in 1979 Revolution allowing users to go back to specific points when the story branch doesn't meet a desired ending due to wrong decisions.
92 For example as in Zika 360, case study number 1
93 For example see case studies Disaster Preparedness Simulator and Stay Safe VR, numbers 9 and 5
94 As done in the Auckland City Hospital earthquake simulator: Lovreglio, R, Gonzalez, V., Feng, Z., Amor, R., Spearpoint, M., Thomas, J., Trotter, M., Sacks, R., Prototyping virtual reality serious games for building earthquake preparedness: The Auckland City Hospital case study, 2018
95 ibid

Decision Making

Traditional drills do not improve decision making skills: For example by making participants make decisions in unexpected scenarios, or foster critical thinking skills to be able to respond effectively. This is relevant to all participants: teachers, staff and school children. Traditional drills are often focused only on evacuation via the same route and do not take into account changing scenarios and unexpected events that require rapid decision making.

XR Opportunities

XR can incorporate decision making skills for a huge range of scenarios into simulations that are impossible to recreate in the real world. Decision making is closely linked to feedback. For example, in Ania Design Lab's virtual reality *Disaster Preparedness Simulator*, detailed storyboards and decision pathways were designed for the simulations, that show how each precautionary measure taken in the simulation leads to a specific consequence and level of risk. For instance, if the user in the typhoon simulation chooses to leave their home and go to a relative's house, they get caught by the storm surge and the game ends. Decision making both provides users with feedback on their performance and increases engagement and learning.

XR can also analyse behaviour linked to decision making. For example, in a VR simulation evacuees' viewing directions can be monitored and which elements and objects users are looking at before making their decisions.[96] This type of data is difficult to collect with classic evacuation drills and can be key to identifying what factors influence evacuation behaviour.

XR, in particular VR, supports **problem based learning**, where users are given a task and have the freedom to explore their own lines of enquiry, using their own prior knowledge and/or new information as it becomes available. One of the most frequently lauded educational benefits of VR is its ability to present to a group of users with multiple, incomplete, yet complementary perspectives on a problem, situation within a physical space. This is particularly useful for disaster response scenarios.

In the BRC *Bystander 360 Experience* users are presented with a common situation where someone needs help and the people around are not able to provide it. The experience puts the user in the position of each character in the scene, and makes them listen to their thoughts and doubts about providing support to the affected person. This narrative provides an efficient form of behaviour change and increases decision making skills.

Predictability and Repetition

Traditional drills are too predictable and too repetitive: Several studies have found that despite constraints on time and resources, most school staff identify a need for more realistic drills.[97] Drills often take place in **predictable settings** that do not reflect the reality of being in a major emergency. Often the same drill (for example drop, cover, hold) is repeated over and over, with a focus on improving the time it takes, rather than the quality.

96 Lovreglio, R, Gonzalez, V., Feng, Z., Amor, R., Spearpoint, M., Thomas, J., Trotter, M., Sacks, R., Prototyping virtual reality serious games for building earthquake preparedness: The Auckland City Hospital case study, 2018, p.671

97 For example: Perkins, Jane C.Johnson & Wales University, Preparing Teachers for School Tragedy: Reading, Writing, and Lockdown, ProQuest Dissertations Publishing, 2015

XR Opportunities

Traditional drills can build in injects, be unannounced and find other ways to replicate the unpredictability of a disaster and build critical thinking. However XR can do this in a way that offers many more potential disaster scenarios and **branching storylines**, that more faithfully represent the multitude of often unexpected choices that a student/teacher will have to make in a disaster evacuation/response.[98]

Given the potential to present different scenarios and branching narratives such as **decision trees** in one simulation, as us done for three different disaster scenarios in Ania Design Lab's *Disaster Preparedness Simulator*,[99] XR can overcome this shortcoming easily.

Experiences that integrate digital games techniques and interactivity are particularly effective at overcoming this shortcoming. In *1979 Revolution*[100] each user receives a personalised experience as they make decisions that affect the narrative and how it evolves. The narrative is based on conversation trees, which allow the creators to design different layers and paths to view the experience. No one experience is the same and it is anything but predictable.

Resources and logistics

Traditional drills and evacuation simulations are **costly in time and resources.** Drills can fail from a pedagogical point of view as they require **significant logistical challenges**, including staff, venue and materials.[101] Drills **disrupt the activity** *and running of full schools*, making it hard to organise and repeat, as a lot of coordination is required. They also can only be performed once so if the drill does not go as expected there is not enough flexibility to repeat it.

XR Opportunities

Virtual, augmented or digital gaming environments require significantly less logistical requirements once the technology is made available and as long as schools are able to use it without technological difficulties. Drills with the same level of scenarios, branching storylines and options would require huge numbers of staff, materials and space. XR drills can be confined to one room while other activities in the school continue.

The resources required to produce XR experiences, in particular full VR, will require a substantial upfront investment, but the cost is absorbed by the creators, rather than the school or end user. Where research has been conducted on the cost of XR simulation experiences per person, for example in *Disaster Scope*[102] the cost per student is low (0.33 cents per student per experience).

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98 See Disaster Preparedness Simulator case study 9 for an example of how branching storylines and decision trees are used for evacuation drills in a virtual environment.
99 Case study number 6
100 Case study number 8
101 Rahouti, A, Guillaume Salze, Ruggiero Lovreglio, Sélim Datoussaïd, An Immersive Serious Game for Firefighting and Evacuation Training in Healthcare Facilities, 2017
102 Case study number 9

Emotional Engagement, Empathy and Behaviour Change
Traditional SBDRR simulation methods *do not emotionally engage participants in the learning process* - a key to changing behaviour.

XR Opportunities

XR can combine emotional and analytical learning, with greater impact on learning outcomes and behaviour change,[103] allowing participants to retain knowledge longer than traditional approaches.

Behaviour change is almost always a desired learning outcome of the main SBDRR activities. There are many examples of **XR leading to increased behaviour change**, modifying attitudes and behaviours and increasing collaboration in the physical world. For example, behaving prosocially after embodying a superhero in immersive VR[104] or being more environmentally conscious after cutting down a virtual tree versus only reading about deforestation.[105] 360 VR has been proven to be effective in increasing empathy leading to behaviour change - for example to overcome the bystander effect or to stop bullying among young people.[106] Examples of mixing AR with gaming have shown positive impacts on learning and behaviour change for health education, for example in the Zika 360 experience.[107] Key to increasing behaviour change is designing the XR experience with a combination of emotional connection with analytical tasks like decision making in virtual reality experiences.[108] For example, in Lifesaver VR an emotional connection is generated through strong storyboarding and scripting and user immersion into the characters, and in *Immersed 2.0* this is achieved through a family home that shows flood damage with everyday items that create a sense of connection.

3.1.3 Training: First Aid and Disaster Management

Training is a key activity of SBDRR across the Red Cross Movement. This includes first aid and disaster management training. At the same time, training has been the most consistently proven best use of immersive technology like virtual reality, for example in the medical and security fields, since the first forms of the technology were created. There is significant potential for using XR for disaster management and first aid training.

3.1.3a First Aid

First aid is one of the Red Cross Movement's core activities and often the only training conducted in some communities. First aid is often a core activity of SBDRR, but has a tendency to be one way, time consuming and not engaging.

103 See case study of FEMA's Immersed for an example of this, case study 10.
104 Rosenberg, R. S., S. L. Baughman, and J. N. Bailenson. 2013. Virtual superheroes: Using superpowers in virtual reality to encourage prosocial behavior.
105 Ahn, S. J., J. N. Bailenson, and D. Park. 2014. Short- and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. Computers in Human Behavior 39:235–245.
106 British Red Cross Bystander effect VR and VR Action Labs (case study number 3)
107 Case study number 1
108 For examples of analytical decision making, see the case study of Ania Design Lab's Philippines Disaster Preparedness Simulator (case study number 6), and the example of Auckland City hospital earthquake preparedness simulator (Lovreglio et al 2018)

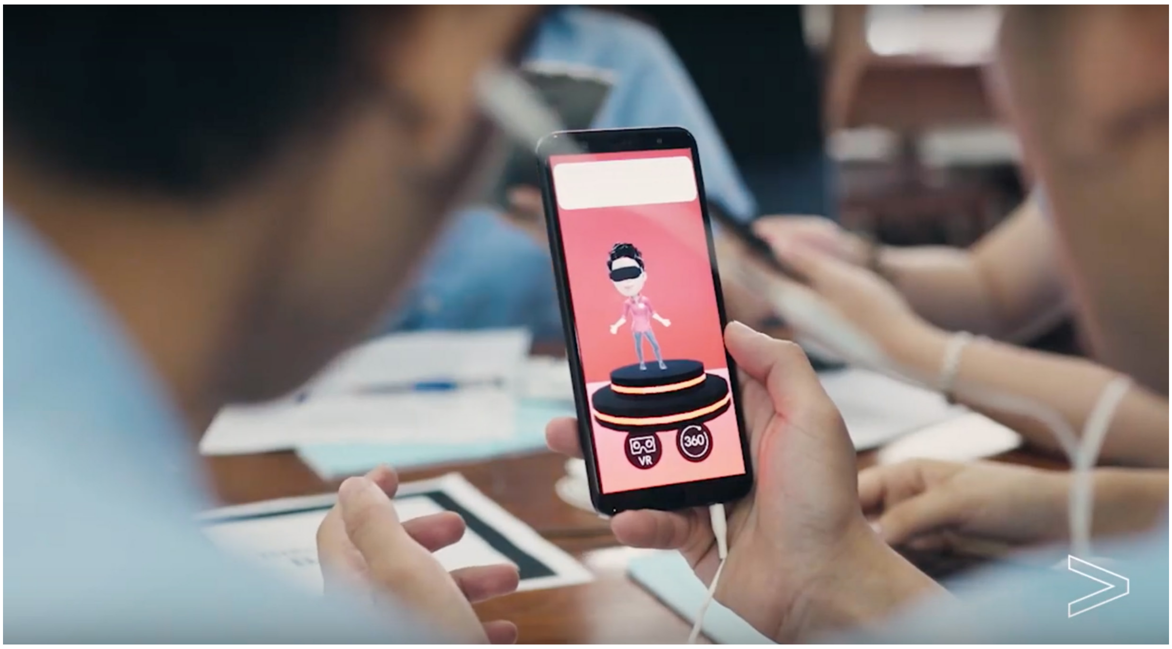
Engagement

First Aid training is not engaging and it is not seen as interesting by trainees. This impacts on knowledge retention and learning outcomes.

XR Opportunities

XR has the potential to turn topics seen as uninteresting into engaging and motivating experiences. For example, the *WWF Free Rivers app*[109] was successful in turning the topic of river health into an engaging topic for school children.

XR, in particular VR, has been proven to increase engagement and learning outcomes in different types of first aid training. Examples of this include improving CPR skills in the *Lifesaver VR* app[110] by Resus UK and the British Red Cross's 360 video VR experience integrated into their first aid training curriculum has been proven to increase the likelihood of overcoming the bystander effect with strangers. BecaXR is another example of motivational experiences. Created by Save The Children and Accenture it uses AR and VR to help disadvantaged vocational school students and out of school youth visualise potential career paths by providing practical life skills to enter the labour market including public speaking and interviewing.



BecaXR promo video screenshot from YouTube

Learning Efficiency and Scalability

First aid courses can be time consuming (from three or four hours up to two days) and expensive, and there is competition in schools over other topics. There is a need to make it easier for schools to teach first aid to children.[111] In addition, *first aid courses would benefit from quicker and*

109 Case study number 2
110 Case study number 4
111 Sukra, E, Pros and cons of first aid training? 2010

repeated methods of teaching, “because the bottom line is that we just want to know that people will get down on their knees and do chest compressions when they see someone in cardiac arrest. Current CPR training is excellent but if that is limiting the number of people taking it, it should be made briefer and easier.”[112] First aid skills are so simple that some researchers wonder if formal training is even necessary. A 2007 study found very little difference in the quality of skills learned by people taking a four-hour instructor-led CPR course and those teaching themselves with a 30-minute DVD and a mannequin.[113] Quicker, more repeated methods of teaching would more likely empower someone to act.

XR Opportunities

XR has the potential to take the critical parts of first aid - such as CPR - and turn them into short, impactful experiences where the user learns by doing, for example in *Lifesaver VR*.[114] Once the experience has been designed and proven to be effective, the training resources needed in terms of time and staffing are reduced, in turn decreasing considerably the cost and resources invested. XR experiences can then be repeated often at little cost, once schools have the equipment/technology, rather than having to run full-day training courses.

LifeSaver VR is successful at providing more skills than the mobile application version as participants are able to interact and perform real tasks with instant feedback on their performance.

If built as apps, XR experiences such as *Lifesaver VR* can be delivered via public websites and app stores to reach wide audiences.

Behaviour change

Through traditional methods of first aid delivery it is hard to address one of the largest barriers to action: the bystander effect [115] because it is difficult to simulate a real life crisis in traditional training.

XR Opportunity

The bystander effect can be overcome by just being aware of it and generating empathy through having the virtual experience. British Red Cross’s 360 video VR experience *“Being a Bystander”*[116] is integrated into first aid training courses and has been proven to increase the likelihood of overcoming the bystander effect with strangers. The experience places the viewer in a train where someone has collapsed, and from the perspective of all the carriage occupants the user experiences the typical responses of people who are not sure whether to take action. After the simulation, training participants discuss the various perspectives and what they would have done and do differently next time. Experiencing the situation in such an immersed, realistic way, makes people more likely to act the next time they are in that situation.

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112 ibid
113 ibid
114 See Lifesaver VR case study number 4
115 BRC First Aid 360 VR Bystander Effect
116 https://www.youtube.com/watch?v=KrrJMu-IjUA&feature=youtu.be

Accessibility
Traditional forms of first aid are hard to teach more vulnerable groups, for example those with high illiteracy rates.[117]There is also a lack of inclusivity of disabilities and special needs when designing trainings, SOPs and simulations.

XR Opportunity

XR can be designed to require less written content and therefore be more accessible to illiterate groups, as long as they have access to the technology. For example, *Lifesaver VR*[118] contains very little written text, and the text there is could be spoken. *Being a Bystander* contains no written text. VR for the visually impaired is still far from having acceptable solutions. Accessibility settings for devices should be enabled to allow for larger text and spoken alternatives.[119]

3.1.3b School Disaster Management Training

Disaster management training for staff or school risk reduction teams includes training in how to lead an evacuation, training on the content of disaster SOPs and how to follow these SOPs. A key learning point on disaster management training is the importance of focussing on the skills and training of teachers.[120] This is often overlooked with more focus given to students. However as many disasters have shown, including the Japan earthquake that sparked the development of the AR app *Disaster Scope*,[121] the lack of teacher training in SOPs can lead to the injury and death of students in a major emergency. Learning can be taken from the private sector where companies like Walmart are beginning to use VR to train staff in store operations procedures.

Knowledge Retention
Low retention of information, particularly on disaster SOPs, school disaster risk management plans and how to follow them is reported in traditional DM training methods.

XR Opportunity

The learning by doing approach of XR - in particular VR - has been proven to facilitate learning and enhance knowledge acquisition and transfer.

Studies taken from medical education and training do not indicate that VR should take the place of other forms of education, particularly the early stages where new knowledge is received but rather that it should be utilised at the assimilation stage, where learners take that new information and apply it, as in the case of doctors applying new surgical knowledge.[122]
In the example of disaster management training, knowledge could be delivered by traditional methods and then put to the test via XR, for example to practice specific hazard SOPs or as part of drills.

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117 ICRC and BRC work on First Aid in vulnerable conflict zones
118 Case study number 4
119 See Chapter 5 for ideas for future research, including on inclusion in XR.
120 Suggested as an area for future research in Chapter 5
121 Case study number 9
122 Gordon, E, Virtual and Augmented Reality in Education, A Review of the Literature, British Red Cross, August 2017

An example of putting knowledge into practice is VR learning company Strivr that has worked with Walmart on operations process procedures to train store managers as well as to evaluate employee performance. Inside the simulated environment, candidates might find themselves standing in a busy aisle facing multiple problems, such as spills, misplaced items and trash, and being given 30 seconds to figure out which to resolve first.[123] According to Walmart, the virtual assessment helps eliminate bias from the internal hiring process.

Engagement

Lack of engagement with the topic. This is particularly because hazard SOPs are not always designed in a participatory way, or that the content is not considered engaging or interesting.

XR Opportunity

XR has the potential to make a topic like *Disaster SOPs*, often considered uninteresting, more engaging and participatory. See section on "Engagement" under First Aid training.

Feedback and M&E

Feedback to participants and monitoring and evaluation is rare and therefore there is little evidence of how effective trainings are or how to improve skills based on trainings.

XR Opportunity

As with disaster drills and evacuations, XR has the potential to integrate feedback in a cost effective and safe way, both in the experience (both directly to the user, or to the developer/ owner/ instructor via analytics) and out of the experience. See drills section on "Feedback" for more details.

For disaster management training, XR provides the opportunity to focus on feedback to teachers or members of school DM committees to improve their training in safety procedures or SOPs. Some examples of this include security training used by IFRC in their *Stay Safe VR* app that trains delegates how to choose safe residences, using 360 video for immersion. Auckland City Hospital's *Earthquake Simulator* trains hospital staff in building evacuation. And Harmony Lab's *VR Action Lab* can be used to train teachers in prevention of bullying, when combined with a curriculum. This last example shows how the same XR experience can be used to train both students and teachers when accompanied by a broader curriculum with specific key messages per target audience.

123 https://www.washingtonpost.com/technology/2019/07/12/walmarts-latest-tool-assessing-whether-employees-deserve-promotion-virtual-reality/?noredirect=on

3.2 XR design, production, delivery, distribution and monitoring: learnings and analysis

The vast and diverse membership of the Red Cross Red Crescent Movement with 190 National Societies, IFRC and ICRC make it difficult to provide XR solutions in a one size fits all approach. When choosing the type of media and designing and rolling out an XR approach or experience, it is important to consider the breadth of the Movement and the needs for an adaptable and scalable approach.

The GDPC supports innovation and learning in disaster preparedness across the Red Cross Red Crescent Movement and therefore any XR design would ideally be scalable across a range of National Societies. The technical capabilities, HR and funding resources of National Societies vary greatly, from those developing VR simulations like the Republic of Korea Red Cross, to those that have very limited budgets even to allocate staff to run and maintain the technology required. Even the most scalable option is not always scalable in low income or under resourced contexts. For example, in the Philippines, the most cost effective VR option chosen by Ania Design Labs when producing their *Disaster Preparedness Simulator* was still considered too expensive by some local officials, due to the cost of the smartphone.[1] National Societies with the most limitations are likely to also be the target audience, with more need for innovative disaster preparedness. Therefore XR tools and their delivery should be made as cost effective and user friendly as possible to ensure take up and maintenance by National Societies with low resources or technical expertise. A sustainability plan is critical to ensure that the experience is well used after creation and distribution.

This section summarises key considerations and opportunities on XR production, design, delivery, distribution and monitoring taken from learnings from the ten case studies[2] and a host of academic and educational literature reviewed as part of this study. The section builds on learnings already presented in section 3.1. The above realities of the RCRC Movement have been taken into consideration when presenting these key considerations.

3.2.1 Design and production

Design process

When designing any educational experience there is a **need for an educational framework** to present why it makes sense to use a particular type of technology. The specific characteristics of the RCRC Movement should be considered when selecting the approach or technology and designing the experience. **Any solution needs to be scalable**. For example, it may be pertinent to sacrifice quality of graphics to achieve a technological setup that is easier to use (e.g. affordable headsets with smartphones vs. expensive gaming laptops with attached headsets).

The most successful examples of XR for disaster preparedness, or indeed XR more broadly, are when **the intended learning outcomes are identified and defined first**, in order for the

1 See Disaster Preparedness Simulator case study (number 6). The technology selection was a smartphone and Google cardboard for immersive VR.
2 See annex A, Case studies

ogy and approach to meet the learning needs rather than being led by the technology. Prioritising learning outcomes will help inform **how to choose the XR media that fits the needs**. For an overview of the pros and cons of different XR methods see the Technology Review table in section 3.3. **Any educational immersive technology programme should have a clear pedagogy or theory of learning in the design and not be subservient to any particular pedagogy or the properties of the technology.** As XR is still new and constantly evolving, the hype surrounding it has meant that this has not always been the case, or that the technology has dominated the learning outcomes during the production process. **Regularly checking in with the intended learning outcomes** is a key design principle to not being distracted by the "cool factor" of new technologies. **User testing** can help with this process and sufficient time should be incorporated into the design process for this. **Considering the XR type of choice as a concept** rather than a certain type of technology will help the technology to keep focussed on and meet learning outcomes.

Considerations for XR media selection in addition to learning outcomes should include age range and what balance is required between personalisation and controlling the narrative (for example, augmented reality allows more personalisation or customisation of an experience and virtual reality allows for more control of the narrative). There needs to be a clear advantage in selecting a particular technology, or combination of technologies - there is no one size that fits all. XR may not be the solution for all training, awareness raising, or simulation needs. In some cases, XR for education or training needs will only be applicable at certain stages in an overall process. See Section 3.1.3b for more on applicability of XR at different stages.

For children, young people and adults, a **triadic design** that balances the following three criteria during the design process is often successful: **reality** (how the game is connected to the physical world), **meaning** (what value needs to be achieved), and **play** (how to create playful activities).[124] The correct balance of these three ingredients will depend on the audience. Younger audiences benefit from more play and less reality, but older students and young people can benefit from greater reality, where there is less risk that the key messages and desired outcomes will get lost in the gamification of serious messages. FEMA explain the rationale of less gamification in their VR experience Immersed 2.0[125] despite user requests for more: "The danger with gamification is that it becomes more about doing damage than about what to do about the risk and the damage. It can increase engagement and numbers of participants and users, but does not lead to the same result." FEMA does however recognise that with younger audiences gamification of serious topics may be more appropriate to deliver key messages. It is key to **balance the requests of users with behavioural science** to ensure learning outcomes can be achieved, particularly in participatory design processes.

For achieving learning outcomes of Red Cross Red Crescent SBDRR programming and ensuring the XR experience not only complements but also addresses the range of traditional shortcomings, **participatory design that incorporates students, teachers, local officials and government and RCRC volunteers is critical**. This will ensure: 1) the accuracy of the content, particularly important with disaster preparedness key messages that often need to be approved by Government, or that are set by Government and the National Society follows; 2) the relevance of the

124 Rüppel and Schatz, 2011, in Feng, Z. Vicente A. González, Robert Amor, Ruggiero Lovreglio, Guillermo Cabrera-Guerrero, Immersive Virtual Reality Serious Games for Evacuation Training and Research: A Systematic Literature Review, 2018
125 See case study of FEMA's VR experiences Immersed and Immersed 2.0 (case study number 10)

content; and 3) the ability to include the experience into the national disaster management curriculum and integrated into broader SBDRR training packages. A user focussed participatory design process can be time consuming, but ensures that the experience is used post-development. For example, Ania Design Lab spent approximately six of the eight months of the *Disaster Preparedness Simulator*[126] production in a "co-design process" developing the scenarios, storyboards and decision pathways together with representatives from local government, schools (teachers and students) and community partners. Data was also gathered from the National Disaster Risk Reduction and Management Council. The process was challenging and time consuming, but allowed the developers to fully understand what kind of VR scenario they should be developing and ensure the technology delivered the learning outcomes and was in line with national requirements. Harmony Labs's *VR Action Lab*[127] also included a highly user-centred design approach and this allowed them to both engage more young people and to achieve better results. IFRC's Zika 360 worked with National Societies, communities and schools in a participatory experience that gathered user feedback and worked in partnership to deliver the experience. Examples where this user-centred participatory approach was not taken have compromised the accuracy and alignment with RCRC or government disaster messaging, ownership of the content and relevance of the experiences.[128] When co-designing experiences, it is important. Creative autonomy in the design process should add to, and not compromise, the framework and process.[129]

Remaining relevant in a rapidly changing technological landscape can be challenging. Creating a solid and well developed experience can allow for building on the original work with new storylines or new technologies without having to start from the beginning. Two examples of this are the digital game *1979 Revolution Black Friday,*[130] where the developers built a new branch of the storyline in VR after the original app-based game, and FEMA's *Immersed*,[131] which was originally built with gaming laptops and HTC Vive headsets and is now being converted to an app for Samsung Gear VR to allow for greater scalability. FEMA are also using the 3D assets of Immersed to build a new version, Immersed 2.0, targeted at a different audience. **Forward planning based on forecasted advancements in technology is important** when working with technologies that are evolving rapidly over a short period of time, to provide options to remain relevant.[132] Equally, **implementing continuous improvement and growth** to update the content and functionality of the applications in order to keep users engaged and content relevant is key. This learning is documented by the team at Save the Children and Accenture's XR team during the pilot phase of their collaboration for BecaXR, as well as by Harmony Labs during their production process of VR Action Lab.[133]

Inclusivity and diversity should be a core design principle. This is a responsibility for the designer of any experience because XR has the potential to have an impact on inclusion in the real world, as the case study of VR Action Labs shows with regards to bullying.[134] There is

126 See case study number 6
127 See case study number 3
128 For example the APDRC's VR based disaster resilience training, case study number 7
129 See case study number 3
130 See case study number 8
131 See case study number 10
132 See chapter 5 for the future technology landscape
133 See case study number 3
134 See case study number 3

also the potential to increase discrimination if not designed inclusively. For example, in video games female characters are commonly shown as hypersexualised and subordinate to male characters, none more shocking than the VR video game "Rape Day" that caused international outrage.[135] Conversely, there are examples of VR being used to increase empathy of minority communities or vulnerable groups, including Stanford University's Virtual Human Interaction Lab's projects on empathy at scale, for example that allow the user to become homeless or experience life as a person of colour.[136]

The **design process**, whether managed internally or with an external agency should have a dedicated focal point with time in their job description for managing the production process and agency liaison. Iterative design processes are the most effective, with ample time to perfect the content, including time built in for user testing with the target audiences and making changes based on this feedback.

Content and functionality

All countries have a different range of disasters and national requirements for SOPs. Therefore any **XR solution should be customisable to the national and local context to be scalable** across the RCRC Movement. Customization for different hazards would also be beneficial, although beyond gaming this requires building different VR or AR scenarios. Auckland City University's VR/AR Lab is currently exploring building a multi-hazard VR gaming platform that is customisable that could be licensed to customers like the Red Cross. This could be an interesting model for the RCRC to consider in the future once the technology becomes more accessible and once they have built a range of hazard prototypes.[137]

The **translation of experiences into other languages is at times not sufficient to engage other countries or cultures** in integrating a curriculum and approach into their schools, as was the experience of the *VR Action Lab*.[138] The curriculum was translated, but full localisation of the experience, including tailored video and scripts would have been needed to effectively roll out the project to other locations. In the case of *Zika 360*,[139] the 360 VR video provided an engaging experience to raise awareness and empathy, however scalability was limited due to the localised context of the film footage. **Localisation, for example through 360 video, improves user experience at the place of roll out, but limits scalability to other contexts.**

A main question posed regarding the use of XR for disaster preparedness with school children is **how to communicate risk and provide safety recommendations through the virtual disaster experience without scaring or traumatising children**. As seen in section 3.1, one of the benefits of XR is being able to realistically portray emergency situations. However it is important that various criteria be in place to prevent trauma. AR with headset is particularly realistic but this high level of realism can be frightening, particularly for younger audiences or vulner-

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135 Marika G. 'Rape day'-A virtual Reality Video Game Causes Outrage. Psychol Psychother Res Stud. 2(3), 2019

136 https://vhil.stanford.edu/projects/2015/empathy-at-scale/

137 Earthquake is the only one available to date.

138 See case study number 3

139 See case study number 1

able people.[140] Advocates of the positive effects of the arousal of fear in the experience user[141] state that a moderate level of fear will lead to behaviour change if:

1. The threatening stimuli used to scare are accompanied by recommendations that are perceived by the recipient as effective towards averting the threat
2. The recipient feels capable of carrying out these recommendations in the real world.

Scaring people about a risk without meeting these two conditions is counterproductive and research conducted on "fear appeal models" predict that in this case the individual will try to reduce the negative emotion, for example through risk denial and defensive reactions, instead of learning how to cope with the risk. A realistic VR reconstruction of an emergency situation or major hazard is inevitably scary to some extent - especially to younger audiences. Therefore the use of realistic virtual simulations of disasters should ensure that the above two criteria are met in order not to overwhelm or traumatise younger audiences.

Age restrictions are equally critical for getting the right balance of fear to motivate action but not traumatise.[142] Alternative design methods to achieve this can include sacrificing on the realistic quality of graphics in VR. This does not automatically mean a less realistic or immersive experience but can help to separate the immersive experience from reality.[143] An alternative to realistic simulations could be designing cartoons or low poly graphics - these are documented in the Children and Virtual Reality report[144] as a favourite technique amongst 8-12 year old. It is possible to create a sense of emergency in an experience that maintains a tension that engages the user without being traumatising. For example, the LifeSaver VR app[145] does this through a simple and effective interface, providing quick feedback about performance in real time and generating a sense of urgency. Despite being faced with a friend who has collapsed in the experience, the user is able to repeat the CPR technique until they perfect it and the experience always ends with the user eventually saving their friend, providing a sense of empowerment.

Lack of user feedback in school disaster drills and simulations is one of the primary shortcomings of traditional SBDRR that XR has the most potential to improve on. The possibilities for user feedback and **decision making** are covered in section 3.1.2 under drills and simulations.

Behaviour change is almost always a learning outcome desired of the main SBDRR activities. There are many examples of **XR leading to increased behaviour change**, modifying attitudes and behaviours and increasing collaboration in the real world. This is expanded on in section 3.1.3.

140 See case studies 9 and 3 on Disaster Scope and Action Labs VR.
141 For example as documented in: Chittaro, L., Buttussi, F., & Zangrando, N. (2014, November). Desktop virtual reality for emergency preparedness. Proceedings of the 20th ACM Symposium on virtual reality software and technology, 141-150.
142 See section 2.2.2 on age restrictions
143 See FEMA's Immersed case study number 10
144 Children and Virtual Reality, Emerging Possibilities and Challenges, 2017
145 See case study number 4

XR technologies, in particular for evacuation simulations, **can go beyond the learning outcome of behaviour change, to investigating and analysing human behaviour**. XR experiences have the potential to allow the understanding of behavioral patterns and behavior changes beyond educational and training aspects. This means that it is possible to use this data to improve disaster preparedness targeting and constantly evolve the quality and relevance of the content. By collecting and analysing behavioral data within a simulation, it is possible to reveal behavioral motivation, validate behavioral models, explore decision making, recognize behavioral patterns, and assess user responses under various controlled conditions.[146] There are conditions that will improve the potential to analyse behaviours accurately in XR, for example Feng et al[147] give the example of a VR evacuation simulation that uses a model of a building that the user is familiar with. However this poses a scalability challenge as it is unlikely to be possible to design a model of every single school building. The use of a hypothetical building can not test familiarity with a building layout, which would be a key behavioural factor to assess in an evacuation simulation, however alternative solutions can be used to make users familiar with hypothetical virtual environments, such as letting users navigate around it before the simulation or drill is run or building in AR that uses the actual location and avoids the need for virtual customisation.

Different hazards require significant design differences. For example, earthquake simulations can have much longer and more intricate storylines than fire simulations.[148] In addition, certain XR mediums will be more appropriate for specific hazards. For example, it is difficult for AR with headset to simulate an earthquake at the time of writing, but it is very effective for flood or fire smoke. This is predicted to change in the near future.[149]

Other content and functionality ideas reviewed that add to the quality of an XR experience include:

- Using a **combination of appealing visuals plus gamified content** increases use of XR applications and positively impacts on awareness raising.
- The **use of a real life props** that add to the immersive experience of VR, for example the use of a pillow to practice chest compressions in Lifesaver VR.[150]
- **Keeping the content simple and focussing on specific key message(s)**. Simplifying the experience's features to the minimum can be very effective in achieving targeted goals. For example in AR experience Disaster Scope fire evacuation training, the main message to children is that they should evacuate the premises by crawling.
- **Language customisation** is necessary for full scalability.

146 Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. Computers & Education, 59(2), 661–686.
147 Feng, Z. Vicente A. González, Robert Amor, Ruggiero Lovreglio, Guillermo Cabrera-Guerrero, Immersive Virtual Reality Serious Games for Evacuation Training and Research: A Systematic Literature Review,
148 Auckland EQ protopype research, p. 680
149 See chapter 5 on Technology: Looking to the future.
150 See case study number 4

Partnerships

Leveraging partnerships for XR development and roll out in the humanitarian sector will lead to greater impact. There are various examples of models from case studies reviewed that can provide inspiration for future GDPC partnerships, both internal and external to the RCRC Movement. Specific opportunities for potential future partnerships are included in Chapter 5. The following are a summary of learnings from the case studies reviewed in Annex X and literature reviewed that apply as general principles for XR partnerships.

- A commercial partnership with a technology provider, as with Disaster Scope, can be beneficial to scale the project as well as to maintain the technological standards and maintenance.
- When working with commercial companies it is important to own the copyright. There are limitations to scalability that come from working with a commercial company that issues licencing fees and retains the copyright. For example, The Republic of Korea Red Cross has not been able to scale up their virtual reality based disaster resilience training simulations to the scale they would have preferred due to restrictive licensing arrangements.[151]
- Having an established and ongoing relationship with a digital agency is beneficial. It can help to keep costs down and allow the continuous and cyclical updating and refinement of the experience as user feedback is gathered.
- There are clear content relevance and cost advantages of working with local design companies and through local partners.
- Collaborating with academic institutions and experts to generate evidence and research papers can bring a more rigorous and scientific approach to a project, highlighting the potential of the project as well as to open new pathways for investigation.
- Working with academic research groups could be beneficial to pilot test experiences that could further developed and be scaled following extensive user testing.

3.2.2 Delivery, distribution and M&E

When planning an immersive experience to ensure behaviour change is achieved, the delivery, distribution and monitoring and evaluation is as important as the design process to ensure a sustainable impact. Even the best designed experiences working in partnership with top agencies and incorporating participatory design features can not surpass the pilot phase if delivery and sustainability is not well planned.[152] Or, the experience can be effectively delivered and knowledge about mitigation actions transferred[153] but users still need to be empowered to act upon these mitigation tips.

Integration into broader SBDRR training

The number one rule of XR delivery is that an XR experience should not be delivered in isolation, but should be integrated into a broader learning experience that includes measurable learning outcomes. The type of XR and the desired outcome will dictate the level of integration that is needed into broader training courses or curricula. XR is often used for creating empathy to raise awareness of issues that can contribute to fundraising. This is being used extensively

151 See case study number 7
152 For example, Harmony Labs VR Action Lab that has not moved beyond a pilot (case study number 3)
153 Such as FEMA's Immersed, see case study number 10

across the humanitarian sector through 360 VR, for example through the Climate Centre to help visualise the effects of climate change[154] and the ICRC to raise awareness of the impacts of war on civilians in their applications *The Right Choice*[155] (360 VR) and *Enter the Room*[156] (AR). These tend to be used as standalone experiences at events and conferences.

XR experiences for SBDRR and for student learning **work best when integrated as part of the learning curriculum or as an adjunct to face to face training and not standalone**. This is important because XR experiences are short and should remain focussed on a small range of key messages to not overload the user. In addition, messages around disasters should be in line with national curriculum requirements. AR for DRR in particular can come with limitations to knowledge acquisition and the immersive experience will not achieve all the desired learning goals by itself. For example, *Disaster Scope*,[157] a cutting edge AR app that allows students and teachers in Japan to experience floods and fires, is extremely effective at making the user experience what these disasters would be like, but does not specifically instruct the user in detail as to what to do in the disaster to stay safe, or on more detailed SOPs.[158] There are a range of example of XR being used as part of training packages that improve learning outcomes when combined with a classroom element. For example *Lifesaver VR*[159] combined with face-to-face training leads to improved learning outcomes for several key elements of successful CPR. Integrating the WWF AR *Free RIvers*[160] experience in a classroom training kit with the teacher as the presenter of the app was effective with schools. The Amercan Red Cross' *Monster Guard* disaster gaming app for kids comes with lesson plans and accompanying activity guides on the website.

It is also important that XR be used to promote the learning outcomes that it is most suited for and complement other methods like face to face training because although XR can encourage taking action like calling 911 or overcoming the bystander effect, skills learnt in XR might not be 100 percent accurate (such as chest compression depth).[161] This added to the fact that VR simulations should last for a maximum of 15 minutes makes the integration into broader curricula key.

Google and Harmony Lab's *VR Action Lab* effectively executed this concept of developing a curriculum for schools with the VR experience by designing a six-lesson curriculum including a design toolkit for VR media makers and organisations, a curriculum guide for teachers and an issue briefing book. The curriculum can be carried out as a complete set or cherry picked according to needs. The curriculum booklet is aimed at teachers and also includes information about how to use VR in the classroom, best practices, exercises and recommendations. VR Action Lab's experience reinforces the need to integrate media experiences within the wider classroom context. Providing the experiences integrated in the curriculum gave students the means to achieve the goals of the project. There has not, however, been the extensive desired

154 *https://www.climatecentre.org/news/798/at-d-c-days-virtual-reality-puts-players-in-driving-seat-on-disaster*
155 *https://visualise.com/case-study/the-right-choice-icrc-red-cross*
156 *https://info.icrc.org/enter-the-room*
157 *See case study 10*
158 *With the exception of teaching users to crawl on the floor to avoid smoke and evacuate the room.*
159 *See case study 4*
160 *See case study 2*
161 *As proven in VR first aid training simulations from the British Red Cross and Resus UK.*

roll out across middle schools in the United States, partially due to the fact that the school administration was not involved in the development - a key learning point when working with schools to develop XR for DRR.

Another example of training curriculum integration is Ania Design Lab's *Disaster Preparedness Simulator*. They deliver their XR experience in schools as part of a one hour training package designed to supplement the Disaster Readiness and Risk Management modules of the Philippine basic education curriculum. This allows for a briefing, the simulations and a debriefing with feedback where further information on hazards and disaster preparedness is disseminated to the students, including IEC materials. The debriefing also provides the opportunity to discuss and provide feedback to users on their performance in the simulation and any issues that arose. Instructors are encouraged to allow users to interact and discuss with each other, sharing insights and experiences from the simulation with their peers. This also allows the instructor to gather data via observation of the discussion.

Distribution options

Various models of distribution of disaster XR experiences exist, depending on the technology. Scalable options like smartphone/tablet VR or AR downloadable on app stores increase uptake and are easily distributed. Less scalable but higher quality options like HTC Vive headsets that require gaming laptops to work usually can only be used with the owner of the experience. This is the case with *Immersed* and the ICRC's simulations, including the BRC first aid and APDRC/KRCS earthquake simulation being built in 2019. In order to allow scalability of the APDRC's fire and cruise ship simulations across Korea and other NS they support[162] they purchased a series of laptops and headsets for each NS and brought focal points to Seoul to take part in a training of trainers to roll them out across their NS. There has been no evaluation of how these are being used across the NS, but it is a good example of scaling a VR experience in multiple NS. A similar model with stand alone headsets or headsets with smartphones would be a more cost effective way to replicate this model in the future.[163]

A potentially interesting model for distribution could be in partnership with a third party - for example a telecoms company or a software developer - offering a rental service option. This is the model used by *Disaster Scope*[164] in Japan and could be beneficial for other schools and local authorities as this method removes the difficulties of updating and maintaining the technology, while saving costs per trained user.[165] This could work well in NS with limited capacity to update and maintain the technology.

There is currently a gap in XR experience and knowledge sharing across the Red Cross Movement. Some RCRC actors interviewed for this research were unaware of other XR initiatives within the Movement that could have provided useful insights and learning and informed their decisions on XR media, technology, design and distribution. There is an opportunity for the GDPC to act as an information and knowledge sharing hub for XR, or this could be taken a step

162 Philippines, Nepal, Republic of Korea, Mongolia, Singapore, Thailand, Vietnam and Indonesia
163 The estimated cost of quality standalone headset vs gaming laptop and headset,for example as used by ICRC, is 1/10 - 4000 USD vs 400 USD
164 See case study number 10
165 The estimated cost of using Disaster Scope in public school is only 0.33 cents per user in Japan

further to create a centralised experience development team that could share expertise and technical support across the Movement. Creating a project with publicly available resources could be useful to other organisations interested in the work. A framework for collaborative best practices would also be beneficial, not only for technology but also XR strategy. This kind of material could be shared by GDPC in a common hub or resource for organisations and practitioners.

M&E

Very little thorough monitoring and evaluation exists for the XR initiatives reviewed in this research. Most experiences only gather anecdotal feedback or post-distribution surveys that give a sense of the users experience but are not robust in showing the impact on behavior change or the particular learning outcome. In a field that is so new and where evidence of impact is lacking, particularly in XR for school disaster preparedness, building in an evaluation system and ensuring outcomes are measurable from the inception of a project will help not only that particular project but contribute to the body of evidence of the benefits of XR for SBDRR. In the case of Lifesaver VR[166] that did research the impact of the VR experience, research papers showing evidence proved the importance of the tool in improving CPR skills. These can be used for advocacy as well as to further develop the experience. Working with academic institutions can add rigour to the evaluation process, for example the work of Auckland University on the Auckland City Hospital Earthquake simulator.[167]

3.3 Technology Review Table

This table reviews all the main forms of XR technology, and presents their pros, cons, and applications. Although it is recommended to start any experience design from learning outcomes and not the technology, this table is a reference that can help determine the best choice of tech to fit the SBDRR or wider DRR need. The table can be found here:
https://docs.google.com/document/d/1pe0PUrzErMs7pzQtPNuYOkqm1FByy1N4t58HVoE5C38/edit

3.4 Decision flow

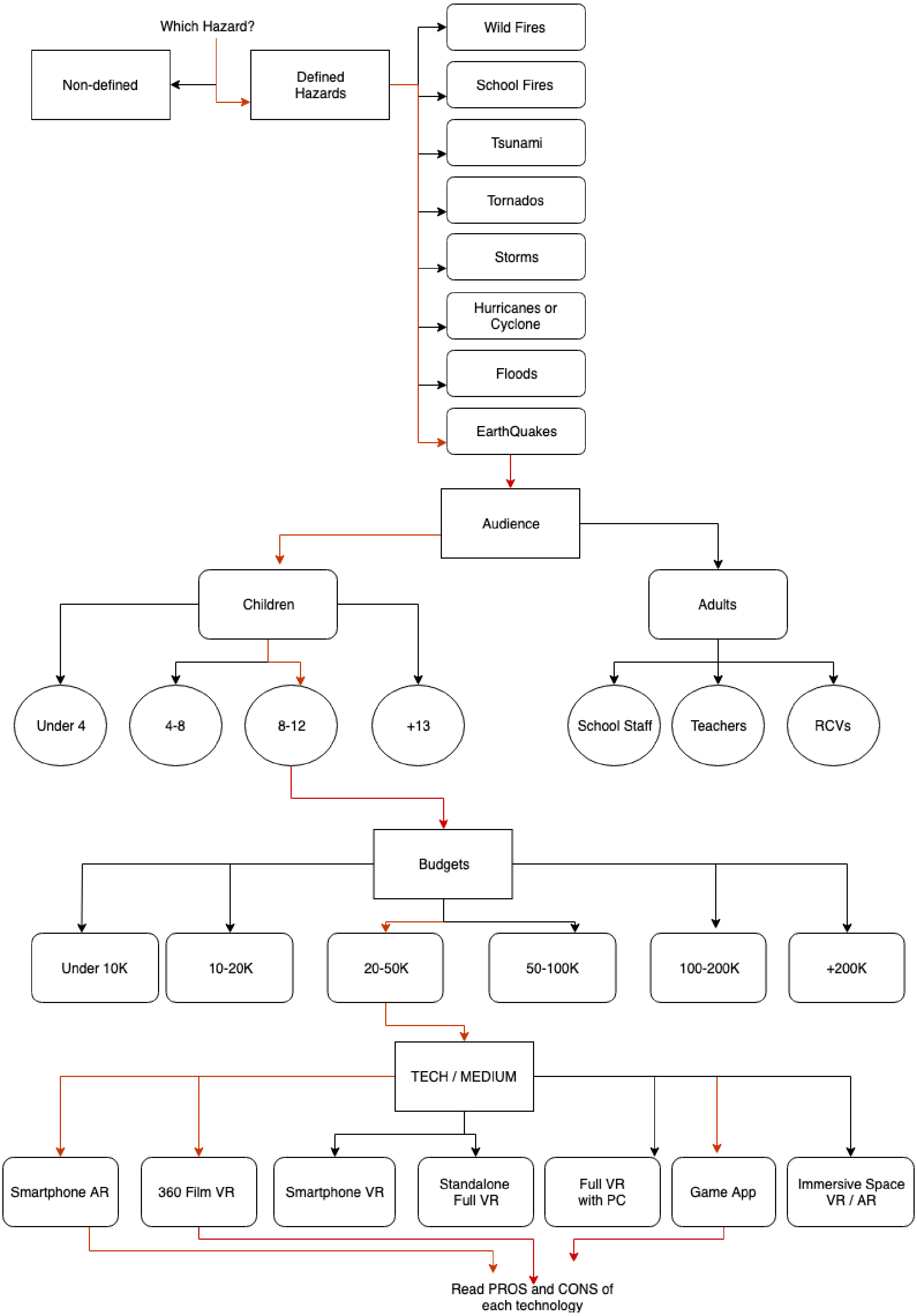
Decision flow charts can be used to define the best approach to building an XR experience for specific SBDRR activities. A decision flow has been created for drills/simulations as an example. It is advised that the GDPC produce a similar flow chart for whatever activities are prioritised for XR. Decision flows can also be built from other entry points, for example specific hazards, learning outcomes or budget availability.

The example below shows a flow chart to plan an earthquake XR experience, for a target audience of 8-12 years old, with a projected budget of 20-50K. As shown in the chart, the options

166 See case study number 4
167 See Partnerships section of Chapter 5.

include: Smartphone AR, 360 VR and game app. Options would have to be considered based on learning and project outcomes.

The full chart can be found here:
https://drive.google.com/file/d/1_WA47ogqz1ZPvpDeG9EPMEV0iL8TTA3x/view?usp=sharing



#4
Solutions & Recommendations

> *"You should do impossible things in VR.*
> *You shouldn't do things you would do otherwise."*
> **Jeremy Balinson, Recode Decode interview**

4.1 Immersive experience solutions for SBDRR

Chapter 3 highlights that immersive technology not only has the potential to address some of the shortcomings of many of the traditional approaches to SBDRR, but can go beyond addressing these shortcomings to adding value to DP/DRR learning outcomes, ultimately contributing to protecting and saving lives.

Based on the SBDRR and technology landscape presented in Chapter 2, and building on the learnings from Chapter 3 on both the affordances of different types of XR technologies and learnings on the design, production and distribution, Chapter 4 presents four models that are recommended to be applied to SBDRR in the present and very near future, integrated as part of training modules and curricula. These can be viewed as a menu of XR "recipes" with recommended ingredients for the GPDC and partners. The first two models are types of XR experiences (virtual simulations and location based experiences) and the second two are functionalities (digital game-based learning and social collaboration) that should be built into the XR experience of choice and that will increase engagement, motivation and collaboration in the real world.

These are followed by a summary of key recommendations when using XR for SBDRR, that can also be applied more broadly across the DRR sector.

4.1.1 Virtual simulations for training & learning

Virtual simulations are extensively used for educational purposes. As seen in Chapter 3, simulations can provide a range of benefits for SBDRR training, from increased awareness, visual representation, behaviour change and knowledge retention. Virtual simulations are best recommended when it is expensive, impractical or dangerous to allow users to experience something similar in the real world. In such situations, which can include any hazard or disaster, users will spend time learning valuable lessons in a "safe" virtual environment. Often the convenience and advantage is to permit mistakes during training for a safety-critical system and to receive feedback on and learn from these mistakes.

In immersive virtual environments an artificial environment makes participants feel like they are living a "lifelike" experience, despite being simulated. This virtual environment may become so realistic that it is difficult for individuals to differentiate between the virtual and the real world.[168] This is a key consideration in the development of these kind of experiences for children and especially those who have suffered trauma. See chapter 3.2.1 for more information on content design.

Interactive features in the simulation are key to engage users, allow them to make their own decisions and provide user feedback. Interactivity usually involves allowing the user to perform actions such as grabbing objects, moving around and making choices to drive the experience. In the design, teaching methods must be defined to deliver knowledge, providing feedback about the user's progress and response. Feedback can be provided immediately or after completion of the simulation.[169]
Studies taken from medical education and training do not indicate that VR should take the place of other forms of education, particularly the early stages where new knowledge is received but rather that it should be utilised at the assimilation stage, where learners take that new information and apply it, as in the case of doctors applying new surgical knowledge. This indicates that XR is ideal for drills, once some hazard and disaster response knowledge has been delivered via traditional methods, and then virtual drills/simulations can practice what would actually need to happen to carry out SOPs for specific hazards.

Expected learning outcomes
Knowledge acquisition
Knowledge retention
Hazard awareness
Behaviour change
Decision making skills
Acting under pressure

XR medium
Virtual reality is often the preferred tool for simulations to train **for potentially dangerous situations or situations that are impossible to recreate in real life, like hazards**. VR creates a "safe environment" to practice and repeat things that could be dangerous to replicate. VR allows creators to totally immerse users in a simulated and controlled environment. For example: natural hazards, saving hostages, aviation disasters, or working in war zones.

Mixed reality is a new upcoming technique which combines the power of virtual simulations embedded within the real world, offering the benefit of using the physical location as a base to deliver the experience. **AR** is an effective platform for drills and evacuation training however

168 *LaValle, Steven (2017). Virtual Reality. Cambridge: Cambridge University Press.*
169 *See Chapter 3, section 3.1.2 for a full review of feedback options in simulations.*

the level of immersion in AR can be limited due to technical restrictions and because the real world is still visible within the scene. For example, this could be a limitation in the simulation of earthquakes where the whole scene needs to shake.

Tech Notes
The preferred hardware solution for virtual simulations for training and learning are standalone virtual reality headsets with no computer or smartphone needed, as they can offer a quality experience while keeping costs and the technical resources needed to a minimum. For example, the recently launched Oculus Quest.

Also recommended is the use of high range VR headsets with VR suitable high spec smartphones, which offer quality experiences while meeting basic health and safety minimum requirements. These include Samsung smartphones with Samsung Gear VR. The benefit of this type of device is to be able to use the smartphone for other uses, outside the XR experience, as well as the lower cost, making this combination a scalable option. In the higher end hardware range, there are professional VR headsets used along with gaming computers that provide the best quality experience. However, these devices can be costly to scale and hard to manage due to the technical expertise needed. Immersive spaces are also recommended for these types of experiences, where users can safely interact inside a room or a dedicated space.

Software solutions include
Environment: Unity 3D, Unreal Engine
3D Modelling: Maya, 3DS Max, Blender, Cinema 4D
Distribution Platform: Oculus, Steam VR, Samsung Gear VR
Development platform: Android, Windows

Advanced features include:
The following are ideas that can be included in the simulations to add quality, realism, increase scalability and improve learning outcomes.

- Multiple scenes for multiple hazards: The same simulation application may contain multiple scenes which aim to train on multiple hazards. For example, the same application could contain scenarios for earthquake, tsunami and typhoon, such as the Disaster Preparedness Simulator.[170] This allows for a more complete training for students and the ability to select from a menu of options that is suitable to the particular hazards of a country.

- Use of props and physical objects: Physical objects can be added as a reference to a real world object. For example in LifeSaver VR[171] real life props such as a mannequin or pillow can be used to apply CPR, adding a new layer to the immersive experience. The new developments of the Disaster Scope[172] fire simulation include using a fire extinguisher.

- Data integration: Although this is still experimental, it is becoming increasingly possible to integrate data from third parties to include real data about the hazard or location where

170 Case study number 6
171 Case study number 4
172 Case study number 9

the experience is being deployed. For example connecting live flood data to the AR and VR system, or adding weather predictions to a typhoon simulation.

- Haptic Feedback: Haptic technologies allow to feel touch therefore the sense of realistic simulation increases. One approach can be to add motion and vibration to the VR hand controllers, or implement the use of haptic gloves and other wearable devices or peripherals.

Considerations:

- For a full list of pros and cons of specific XR technologies/approaches, see the Technology Review table in Section 3.3.
- The GDPC and/or Movement partners could consider building a series of VR simulations for different hazards that other users could customise for their country/region. If built in VR, it would be possible to provide customisable 3D assets.[173] These could be in one experience and selected from a start menu.
- It may be worth sacrificing quality of graphics and experience for scalability to make simulation solutions viable across a range of National Societies, for example by using standalone headsets like the Oculus Quest or a smartphone/cardboard headset combination.
- Limitations in the technology and the design should be addressed to avoid raising health and safety concerns such as motion sickness. Refer to chapter 2.2.2 for more information on health and safety.

4.1.2 Location Based Experiences

Location based XR has the potential to transform any given location into a disaster zone for training purposes. By overlaying 3D content and immersive sound, the physical scene can be transformed in seconds. The technology to achieve this exists but the design of the systems to employ the technology is not yet fully researched and the potential has yet to be fully understood. However it is already clear that from knowledge retention to behaviour change, location based XR is a perfect solution to create effective and realistic drills and evacuations and is likely the future of XR for disaster preparedness and risk reduction.[174]

In location based experiences, the physical location should be considered carefully. Location based systems such as GPS take the user's location into account when processing and presenting information. Currently, it is possible to track the location where the phone is positioned, such as an individual classroom. However these systems become cutting edge when they can expand their capabilities beyond the room, to full indoor buildings such as schools. At the time of writing this has not been widely applied to disaster management but is predicted to advance rapidly over the next two years with smartphones embedded with this technology.

Supporting indoor augmented reality for evacuation calls for advances in a number of research areas, including accurate and efficient indoor localisation, efficient rendering and user-friendly interfaces, and effective evacuation functionalities that should be built into the experience.[175]

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173 Consider options of using 3D assets already designed by other Movement partners including ICRC
174 For example as is done in the Disaster Scope AR app, case study number 9
175 Ahn, Junho & Han, Richard. (2012). An indoor augmented-reality evacuation system for the Smartphone using personalized Pedometry. Human-centric Computing and Information Sciences.

Indoor localisation, which involves understanding where the user is and creating a virtual map of the building, is a key design requirement for indoor XR systems, however there is no standard for an indoor positioning system. Existing methods include using visual markers positioned at specific locations and wireless technologies such as wifi or bluetooth.

The *Disaster Scope*[176] AR app is an example of how this could work in the future, however it only uses tracking of the room where the phone is located and cannot yet assess a whole school building.

Expected learning outcomes

Behaviour change
Knowledge acquisition
Knowledge retention
Hazard awareness
Decision making skills

XR medium

In location based experiences, **augmented reality** with smartphone and headset/glasses is the preferred technology to use, as it uses a mobile device location settings and camera to deliver the experience, overlaying digital layers of information on top of the physical world. In contrast to virtual reality which completely replaces the real world, augmented reality displays virtual objects and information along with the real world registered to real world locations.

The current advances in **mixed reality** technologies are opening up many more opportunities as the power of new platforms and devices provide a higher quality experience. For example Magic Leap is still a niche product but offers an advanced augmented experience.

In the case of **VR**, location based technologies allow the user to be inside the virtual experience and to match the physical location with the virtual. However they do not make the most of the physical space as they lack a picture of the real world. AR is therefore the recommended medium for location-based experiences.

Tech Notes

The preferred hardware solutions for AR are advanced smartphones with advanced camera and high resolution. The new generation smartphones such as Apple iPhone X and Google Pixel 3 also contain 3D sensors, which analyse the space around the phone. The use of tablet devices with quality cameras is also recommended as their screens are bigger than smartphones, however they cannot be used along with headsets. There are also mixed reality headsets to make the experience more immersive. However the power of **mixed reality** is expected to change with platforms such as Magic Leap and HoloLens. See chapter 5 on the future technology landscape.

Software:

Environment: ARKit, ARCore, custom indoors tracking systems

176 Case study number 9

3D Modelling: Maya, 3DS Max, Blender, Cinema 4D
Development platform: Android, Windows, Apple

Advanced features include

- **Expanded environments:** Mapping and creating a virtual map of the building where the drill or training is happening. In the case of SBDRR, this would mean mapping the school and the exits to be able to create a realistic experience of the real location. The experience expands to other rooms, buildings and outdoors. Using a navigation guide, the user can move around the selected area to discover and explore interactive scenes.

Considerations

- For a full list of pros and cons of AR, see the Technology Review table in Section 3.3.
- Using AR with headsets brings a new world of immersion to the experience.
- AR is effective and impactful but should be used with caution as the high level of realism can be frightening, particularly for younger audiences.
- The technical limitations of AR around space recognition and visualisation have to be researched as the technology is limited. However any current limitations are predicted to be overcome in the next couple of years.
- With the arrival of 5G technologies, the possibilities of this model will increase as the rendering power and location tracking will improve considerably.
- The visual quality and clarity of an augmented reality experience is imperative. If it is not high quality it will cause users to exit the experience and thus can nullify all value of the application.

4.1.3 Digital game-based learning

Digital game learning involves a set of techniques which can be plugged into an immersive experience to increase engagement and learning performance. Students can develop confidence through repeatedly practicing key skills during gameplay. Digital game-based learning, when used appropriately, can provide students and educators with a long list of benefits. Digital game-based learning often facilitates better attitudes towards learning, increases student motivation, fosters higher-order thinking, influence personal real-life perceptions, impacts decision-making processes, and aides students learning achievement.[177]

Digital games and serious games can provide a balanced space between gameplay and learning which is beneficial for teaching disaster preparedness, particularly for awareness raising and knowledge acquisition. The combination of VR and serious games encourages participants to retain knowledge longer than traditional approaches due to full engagement and high emotional and physiological arousal.[178]

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177 Kapp, K. M. (2012), The gamification of learning and instruction: game-based methods and strategies for training and education, San Francisco, in Games and Game-based Learning in Instructional Design
178 Chittaro, L., Buttussi, F., & Zangrando, N. (2014, November). Desktop virtual reality for emergency preparedness.

The basic method is playing the game, which means that the user is in control of the actions and the course of the experience, receiving feedback on their actions during, and after. During gameplay the player works to achieve the game's goals, usually through challenges. Below are some of the **gamification techniques** which have been identified in this research as contributing positively to learning and training:

- Branching scenarios are typical of exploration games and challenge players to navigate a non-linear path with multiple outcomes. By exploring the different paths, users can learn how their actions might influence the outcome.
- Decision making features can reinforce concepts, judge decisions and evaluate outcomes.
- Memorisation features allow to retain information usually by challenging the user to prove their knowledge.
- Simulation games in which players take the identity of a selected character in the game. These characters can take different roles to provide a base for learning different skills.
- Test and scoring systems allow for the analysis of situations, making decisions and cross referencing solutions.
- Motivational elements include providing scores, time counts, feedback on results as well as repetition of mistaken choices or paths to allow the user to learn.

Mobile gaming apps such as Monster Guard and Tanah have been used by GDPC in the SBDRR field and there is some internal learning on these as an approach. It is recommended that these learnings also be applied to the integration of gaming techniques to XR experiences.

Expected learning outcomes
Engagement
Understanding content
Developing specific skills
Behaviour change
Knowledge acquisition
Knowledge retention
Hazard awareness
Decision making skills

Tech Notes
Digital games techniques can be applied across all types of immersive technologies. It is recommended that gaming features be added to XR developed by GDPC and partners, particularly when targeting younger students.

Advanced features

- **Multiplayer games:** With multiple players, each user can observe how the other players perform and obtain feedback on their own actions.

- **Difficulty levels:** Adding layers of difficulty opens the possibility for the game to serve different age groups as well as to increase motivation. A way to define levels can be to have multiple players who receive different sets of features with increased complexity, for example beginner, intermediate and advanced.

Considerations

- Where is the balance between easy and difficult? In designing games levels, research and testing should be integrated to assess the right level of difficulty for each age group.
- It is important to strike a balance between user requests for increased gamification and the lessons of behavioural science, that indicate that this can detract from key messages.[179]

4.1.4 Social XR solutions

Immersive social platforms allow people to be together and interact with each other in the virtual space. Positive social impacts and interactions are encouraged by XR learning games, especially collaboration and motivation, leading to more opportunities for students to communicate and collaborate in the real world. Exploring computer-supported collaborative learning, learners perform tasks in groups in order to achieve shared goals. This is a pedagogical approach which can be applied to educational XR. The ability to facilitate this interaction is claimed by some in the field as VR's greatest educational potential.

In an increasingly social digital world, young learners are eager for opportunities for digital interaction, such as interaction with immersive 3D environments and feedback on their actions. Additionally, opportunities for human-to-human interaction within the application and outside of it (such as through social media sharing) support youth interest and engagement, but should be approached cautiously given considerations of user privacy and safety.

Expected learning outcomes

Social engagement
Behaviour change
Knowledge acquisition
Knowledge retention
Critical analysis
Decision making skills

XR medium

Social integration is a common aim for all extended reality technologies, however the focus is on virtual reality as some devices allow for synchronisation of multiple headsets.

Technology Notes:

Selected VR devices are recommended for this kind of experience, which need to be equipped with synchronisation features for social interaction with other players. For example Facebook is leading the development of social applications with a range of developers and companies who are testing new platforms such as AltspaceVR, Vtime and VR chat.

Advanced features:

- Group training in evacuations and simulations, allowing players to interact with each other.

179 *See case study 10 for example of FEMA and the research they did in behavioural science, although this was for an adult audience.*

For example a teacher could realistically lead a building evacuation as they would in real life. This overcomes the issue of experiencing simulations where there are no other characters, one of the shortcomings of many current VR evacuation/drill simulations.

- Group gaming, for examples in multiplayer competitions in hazard knowledge or knowledge of SOPs.

Considerations

Necessitates multiple headsets and therefore would be more costly and less scalable.
As players are able to interact freely with each other there are some considerations around moderation of their interaction, especially in children.
This technology is still in its infancy and this field is not yet well researched.

4.2 Summary of Key Recommendations

The following is a summary of key recommendations for the GDPC and partners when considering using XR as part of SBDRR. These can also be applied more widely across the DRR sector. The recommendations condense the analysis of Chapter 3 and build on the proposed models in section 4.1.

Defining an approach and learning outcomes

- It is critical that intended learning outcomes are identified and defined first, during the project conception, in order for the technology and approach to meet the learning needs rather than being led by the technology. Any educational immersive technology programme should have a clear pedagogy or theory of learning in the design. Pedagogy must be given equal consideration during the design process.
- Consider the XR type of choice as a concept rather than a certain type of technology. This will help the technology to meet learning outcomes, rather than the focus being on the technology type itself.
- Any use of technology must not recreate education as it already is but utilise the unique affordances of the technology to bring added value to what is already in practice with other learning modalities.
- Design and integrate the XR experience as part of a training module, curriculum or approach, and not as a standalone experience. This aspect should have as much weight as the XR experience design.
- Consider the specific characteristics of the Red Cross Movement when selecting the approach or technology and designing the experience. Any solution needs to be scalable. For example, consider sacrificing quality or detail of graphics to achieve a technological setup that is easier to use.
- Explore computer-supported collaborative learning where learners performing tasks in groups in order to achieve shared goals. This is a pedagogical approach which can be applied to educational XR. The ability to facilitate this interaction is claimed by some in the field as VR's greatest educational potential.
- Adopt an organisational openness to taking risks on new ideas or technologies: this is key for innovation.

Experience design

- Design the experience in participation with target users and include students, teachers, community leaders, local/national government, and RCRC volunteers. This will ensure the accuracy and relevance of the content and the ability to include the experience into the national DM curriculum and as part of broader SBDRR training packages.
- Apply a triadic design that balances reality, meaning and play.
- When designing realistic disaster simulations, content should be empowering and follow the principle of self-efficacy[180]: this is the key to overcoming fear in realistically simulated events, coupled with targeting the correct age range.[181]
- Ensure that realistic simulations that can be scary or moving for younger audiences are age-appropriate and accompanied by recommendations that are perceived by the recipient as effective towards averting the threat and possible to carry out in the real world.
- Design introductory messages and warnings to prep users on what they should expect. Consider adding special messages for participants who might have had a previous trauma or disaster experience.
- Consider the design differences required for different hazards. For example, earthquake simulations can have much longer and more intricate storylines than fire simulations[182]
- Forward plan based on forecasted advancements in technology. This is important when working with technologies that are evolving rapidly over a short period of time, to provide options to remain relevant.
- Design with diversity and inclusion as core design principles. This is a responsibility as XR has the potential to have an impact in the real world.
- Implement user testing systems to ensure the design matches the user needs and expectations.
- Design the experiences following best practices to avoid motion sickness and user discomfort.

Experience content

- Capitalise on content and proven gaming concepts already available in the Red Cross Movement. For example, Climate Centre games and Minecraft for community mapping.
- Include a guide in the experience to make the user feel more immersersed and integrated. When this is not done, levels of immersion are lower because it is harder to connect with the topic.[183]
- Create a library of shared 3D assets that can be used to build upon and shared across the Red Cross Red Crescent Movement.

180 The belief that an individual has on his/her ability to execute a behavior.
181 See section 2.2.2 on age restrictions of XR
182 Lovreglio, R, Gonzalez, V., Feng, Z., Amor, R., Spearpoint, M., Thomas, J., Trotter, M., Sacks, R., Prototyping virtual reality serious games for building earthquake preparedness: The Auckland City Hospital case study, 2018
183 E.g. with the ICRC experiences

Health & safety and age restrictions

- Carefully consider what technology is appropriate for the target audience. Age considerations are important, particularly with immersive technologies, and to date this has not been given much prominence to date in XR used with children.
- Any technology needs to come with clearly articulated psychosocial guidance. This should include the age range applicable for the technology and guidance for teachers in how to support students through the experience.
- Teachers or those promoting this technology must take a cautious approach, drawing on manufacturer health and safety guidelines and the substantial research on child development in order to make informed decisions about ethical and safe use of the technology.
- Consider privacy implications of using technology with young people and put safeguards in place.
- Any safety warnings developed should include notes about how to use headsets, how to set up a safe space, what are the common risks associated with XR and what to do in case of discomfort.

Production process

- Regularly check in with the intended learning outcomes during the production process. This is a key design principle to avoid being distracted by the "cool factor" of new technologies.
- User testing is critical and sufficient time should be incorporated into the design process for this. As this is an emerging field, any project must be committed to ongoing refinement of the product based on testing with end users.
- Designate a focal point to manage the process, with time built in to their job description.
- Consider the copyright and ownership of the materials and the experience itself, and how they will be safeguarded over time.
- Choose your technology carefully with the goal of creating a scalable project.

Distribution process

- Plan distribution and sustainability from project inception.
- Distribute as part of a broader curriculum or training package.
- Involve school administrations to ensure wider distribution and overall success.
- Assess how to adapt the experience to other regions, countries or cultures, bearing in mind that translation is not enough - cultural adaptations and customisations are needed.

Partnerships

- Explore how other XR content could be shared across the sector, with the GDPC as an XR information and resource hub. There are many examples of XR that are not currently being documented or shared and this is a missed opportunity where GDPC can play a role and fill this information and learning gap.
- Create a library of 3D assets for the Red Cross Movement
- Partner with academic institutions - this can be a cost effective use to overcome limited resources and allow for a more rigorous monitoring and evaluation systems.
- Collaborate with other parties that understand the risks, challenges and opportunities and are willing to go where no one else has gone.

#5
Future Considerations

5.1 Technology: Looking to the future

The technological landscape for immersive technologies is in constant development and flux and is predicted to reach wide audiences in the near future. With more creators entering this space, it is expected to see an evolution in the way applications are built and experienced. From the creation of natural interfaces to integrated data systems, the future of this immersive tech space is dynamic and exciting. Below are some of the key considerations which may influence the evolution of XR in the future.

Virtual reality has long been a dream for many technologists and designers. Today it is possible to buy an affordable standalone headset to receive a quality immersive experience without much technical expertise. The next years are predicted to advance this technology to the wider public. One of the key considerations for VR is its application in the professional and business sectors. Given that VR can effectively train and educate people, as shown in this paper, it is expected that many more institutions, corporations and organisations will start implementing VR as a standard training tool for staff and employees. This will also be the case for the education sector that will use VR and other XR technologies to provide a more engaging experience for students. VR combined with haptic devices will provide highly realistic experiences and the feeling of really being somewhere else.

Augmented reality has already been named as the future of design. Its potential for SBDRR is immense and is yet to be discovered. In approximately one to two years, the augmented reality technology used in Disaster Scope[184] such as advanced tracking and sensors are expected to become more powerful, affordable and available at a wider scale, therefore opening a new line of work for researchers and application developers. The impact of AR decreasing in price and mobile phones being more suited for it will be huge. AR in the real world will be effective but there will still be value in smartphone AR/tabletop experience to take people to other places, rather than augmenting their surroundings. This is particularly the case for awareness raising. For SBDRR it will be real world that is the most useful. AR and mixed reality headsets are expected to become more user friendly and soon we will have real world AR glasses or lenses. The combination of AR plus 5G and machine learning will allow us to recognise our surroundings and easily add digital layers and objects over them.

For location-based XR technologies the implementation of **5G mobile technology** opens a new

184 Disaster Scope, case study number 10 world of opportunities by allowing high amounts of data and information to be integrated in real time in the experience. This will increase the rendering quality - the visual quality power for virtual simulations.

During the next two to five years, it is expected to see a convergence of 5G, AI, internet of things and sensors and VR/AR. The combination of all this data will enable us to both map our physical world into virtual space and superimpose a digital layer onto our physical environments. This will offer immense new opportunities, for all sectors. In particular it is possible to envisage how this technology will bring great efficiencies to the fields of disaster risk reduction and preparedness. At the same time it will pose a range of ethical, political and economic challenges. This will take us into another dimension, a hybrid new world.

5.2 Partnerships: Looking to the future

The GDPCs future work in XR will doubtless need to involve partnerships both inside and outside the Red Cross Movement and into the private and academic sectors. This section reviews some of the partnership ideas that arose during the research for consideration as part of future planning, recognising that the GDPC already has established partnerships that they may wish to build on.

ICRC

The ICRC have the only dedicated virtual reality team of the Red Cross Movement based in Bangkok that is open to working with Movement partners to support building immersive VR experiences for internal RCRC clients. Currently, in addition to the work they do internally, the VR team is working with National Societies such as British Red Cross on a first aid simulation, and Republic of Korean Red Cross on an earthquake simulator.[185] The ICRC VR team acts as an agency to serve internal RCRC projects. Advantages to working with the ICRC team include the ability to keep production costs at a low as these are currently largely absorbed by ICRC, although this model may change in the future. Another advantage is to be able to use their library of 3D assets which avoids starting from scratch. The disadvantages are that the ICRC does not provide strategic advice, but executes the request of the client. This is a viable model if the RCRC client knows exactly what they want, but otherwise could lead to a product that is not user-centric or integrated into the broader work of the NS.

Climate Centre

The Red Cross Red Crescent Climate Centre have extensive experience with interactive methodologies to reach out to children and have a specific youth engagement team. The Climate Centre has developed a wide range of games, including within the recently updated Climate Training Kit released in June 2019.[186] To date they have not digitised these games or explored how they could be built in XR, but are interested to do so and to collaborate with the GDPC. They already have games designed for relevant SBDRR learning topics that explain complex systems in a way that is easy to understand. These could be used or adapted for XR content.

185 *See case study on VR training for fire and earthquake evacuation of the APDRC, case study number 7*
186 *https://www.climatecentre.org/training*

For example:

- Early warning systems: https://www.climatecentre.org/training/module-2/subitem-2a
- Exercises leading to the production of a contingency plan, in a gamified way:
    - https://www.climatecentre.org/resources-games/games/1/ready
    - https://www.climatecentre.org/resources-games/games/2/paying-for-predictions

Auckland University

Auckland City University's VR/AR Lab is currently exploring building a multi-hazard gaming platform that is customisable and that could be licensed to customers like the Red Cross. They would like to discuss opportunities for collaboration with the humanitarian sector. It might be possible for the RCRC to test their existing earthquake school simulation free of charge with communities, and the feedback would be useful for their research. In addition, this multi-hazard gaming platform could be an interesting model for the RCRC to consider in the future once the technology becomes more accessible and once they have built a range of hazard prototypes.[187]

Other academic partnerships with institutions already linked to the GDPC would be worth exploring, given the advantages of working with academic institutions to bring a more rigorous and scientific approach to a project, highlighting the potential of the project as well as to open new pathways for investigation.

Private Sector

A potentially interesting model of working could be in partnership with a third party - for example a telecoms company or a software developer - offering a rental service option. This is the model used by Disaster Scope[188] in Japan and could be beneficial for other schools and local authorities as this method removes the difficulties of updating and maintaining the technology, while saving costs per trained user.[189] This could work well in NS with limited capacity to update and maintain the technology.

5.3 Ideas for future research

1. **Next steps:** When GDPC have decided where they would like to focus their efforts in XR, it is recommended to conduct a more detailed piece of analysis on the specific XR medium and SBDRR activity areas of interest to inform product design, choice of software, hardware, costings etc. building on this analysis.
2. **DP training and education for teachers:** Despite the critical role that teachers play in keeping students safe and alive in disasters, as shown in the case study of Disaster Scope, very little of the existing tools or literature focuses on this critical audience.
3. **XR and curricula integration:** The topic would benefit from more research into the most effective way to develop curricula with XR integrated. Some examples of case studies ad-

187 Earthquake is the only one available to date.
188 See case study number 9
189 The estimated cost of using Disaster Scope in public school is only 0.33 cents per user in Japan

dressing this and learnings are reviewed in Chapter 3.

4. **Disability and inclusion in XR:** This is an under researched topic and there is limited guidance on design principles for inclusion. It would be beneficial for the GDPC to look more into this topic before designing an XR experience.
5. **Hazard and XR detailed analysis:** Different hazards require significant design differences and some XR media is more suitable to specific hazards. It is recommended that additional research be conducted on the specific hazards that the GDPC would like to focus on, or that an overall review of specific hazards and their preferred media and design preferences be assembled.
6. **Gamification techniques:** There are many techniques and mechanics in digital and serious games which could be researched and tested to identify the most relevant ones for SBDRR.
7. **Use of haptic technologies:** It is recommended to investigate how much haptic feedback contributes to the simulation experience for disaster awareness and training.

5.4 Conclusion

The age of immersive learning is here and is a rapidly evolving field, however it is still under-researched, particularly for school students, and further studies on the effects of immersion and on the pedagogical potential of XR are essential if the affordances of the technology are to be leveraged for creativity, collaboration and deep learning. Building this knowledge base will take time. There is however already sufficient research to prove the potential for XR to address some of the shortcomings of traditional SBDRR and provide creative, innovative solutions where relevant and possible. This paper presents some of these solutions, key considerations and recommendations both for XR approaches and design and delivery. These include XR technologies that are available now and some that are speculative and will very likely be available at scale in the near future, with monumental impacts on how XR can improve the quality and reach of SBDRR. When working in a space that is constantly advancing and shifting, projections into the future and building experiences that can be updated to reflect the advancements is key.

Ultimately, the decision on where to focus XR efforts in SBDRR should be dictated by priorities in pedagogy, respect of existing well-functioning practices and the realities of the Red Cross Movement, including options and opportunities for scalability. Considering the XR of choice as a concept rather than only a type of technology will help the technology to meet learning outcomes, keeping the needs and safety of students and teachers at the centre of the immersive learning road ahead.

#

Credits

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About GDPC
The Global Disaster Preparedness Center (GDPC) is a joint venture between the International Federation of Red Cross and Red Crescent Societies (IFRC) and the American Red Cross with the aim to expand and enhance disaster preparedness (DP) capacities of the global Red Cross Red Crescent (RCRC) network through a service oriented, demand-driven approach.
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