Definitions of Simulation and Immersive Technologies

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Background and Purpose of this Document

Simulation-based techniques and immersive technologies are core ways for educating the health and care workforce. Alongside traditional education techniques and technology enhanced learning (TEL), they provide opportunities to enhance the competencies and professional capabilities of health and care workers. They prepare learners for future practice, providing a safe learning environment to practice real-world health and care scenarios and unique ways to apply safety science and human factors to improve organisational learning, system performance and staff wellbeing.

Reports such as the Topol Review (2019)[1] establish the need for health service leadership to integrate and adopt new technologies to ensure health and care services remain contemporary and in pace with evolving health and care, including advancements in genomics, artificial intelligence, and digital medicine. This includes adopting new ways of educating and training the health and care workforce, improving quality of care and patient safety, incorporating simulation-based techniques and immersive technologies.

Increasingly, higher education institutions and regulatory bodies are supporting the use of simulation-based techniques. For example, the Nursing and Midwifery Council (NMC) advise that up to 600 hours of simulation-based learning can now be included in the 2,300 practice learning hours that students need to complete to be eligible to join the nursing register[2].

Many organisations are using simulation to improve quality of care and improve patient safety. Embedding human factors and quality improvement methods within the design, operation and evaluation of simulation-based interventions optimises learning and enhances the identification of how health and care systems can be improved to benefit organisational performance, organisational learning, and staff wellbeing. This approach helps enhance professional practice within an increasingly complex and resource constrained health and care environment, and provides insight into the interactions between the people, equipment, technologies, working environments, policies and procedures that underpin routine and emergency practices.

Selecting the most appropriate education or patient safety intervention to achieve the desired learning outcomes or improvements can be challenging. This document provides a basic guide to the simulation-based techniques and immersive technologies available, and some of the key terms. It is not intended as an exhaustive simulation taxonomy or definitive source of information but aims to inform health and care leaders, practitioners, learners and patients about the current simulation and immersive technology landscape and potential future developments.

[1] HEE (2019). Topol Review. Available from: https://topol.hee.nhs.uk

[2] NMC (2018). Standards framework for nursing and midwifery education. Available from: https://www.nmc.org.uk/standards-for-education-and-training/standards-framework-for-nursing-and-midwifery-education/

This document is part of a series of publications produced by the NHS England Technology Enhanced Learning (TEL) Simulation and Immersive Technologies team. Other documents from the series can be found on the NHS Learning Hub. To find out more about the programme, email: england.simimmtech@nhs.net.

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Fundamental Surgery, FundamentalVR

Definitions

This publication provides definitions of simulation, immersive technologies, and blended learning approaches. These definitions provide a foundation for understanding these terms and are fundamental for conversations when considering how to integrate them within various contexts.

Simulation

There are many definitions of simulation when applied to health and care. One of the most well-known and widely accepted, is by Gaba (2004)[3]:

> "Simulation is a technique – not a technology – to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner".

Simulation-based techniques can encompass a wide range of modalities which are described later in this document.

Immersive Technologies

Immersive technologies are increasingly used to build on traditional simulation-based methods by harnessing the capabilities of tools such as virtual reality, accessible through specialised headsets or multi-screen projected setups. NHS England defines immersive technologies as:

> "Immersive technologies describe the broad range of extended reality (XR) technologies that include virtual reality (VR), augmented reality (AR) and mixed reality (MR). These technologies leverage digital immersion to replicate or construct immersive environments, enhancing the way individuals interact with the real world."

[3] Gaba, D. (2004) The future vision of simulation in health care. Available from: http://dx.doi.org/10.1136/qshc.2004.009878

Blended Learning

The use of simulation and immersive technologies is being combined increasingly with other forms of digital and remote learning methods. NHS England defines this approach as blended learning:

> "Blended learning is a method of education that integrates digital technologies with traditional in-person, face-to-face educational and clinical activities, giving students more flexible access to their learning experiences."

By using a blended learning pedagogical approach, educators can provide comprehensive and dynamic learning experiences outside of the traditional classroom setting. By combining in-person interactions, hands-on training, and online resources, students can explore healthcare knowledge in a variety of ways.

Simulation Fidelity

The term, fidelity, is often used in healthcare education simulations to describe:

> "the degree to which the simulation replicates the real event and/or workplace; this includes physical, psychological, and environmental elements"[4]

Fidelity is one attribute that should be considered in the design of simulation-based education experiences. However, it is important to note that higher fidelity does not necessarily guarantee a more valuable learning experience[5]. Numerous other factors influence the benefits that simulation can achieve, including the specific outcomes being sought, the needs and level of experience of the learners, the availability and experience of faculty or facilitators, and the learning environment that is available.

[4] Lioce L. (Ed.), Lopreiato J. (Founding Ed.), Downing D., Chang T.P., Robertson J.M., Anderson M., Diaz D.A., and Spain A.E. (Assoc. Eds.) and the Terminology and Concepts Working Group (2020), Healthcare Simulation Dictionary –Second Edition. Rockville, MD: Agency for Healthcare Research and Quality; September 2020. AHRQ Publication No. 20-0019. DOI: https://doi.org/10.23970/simulationv2

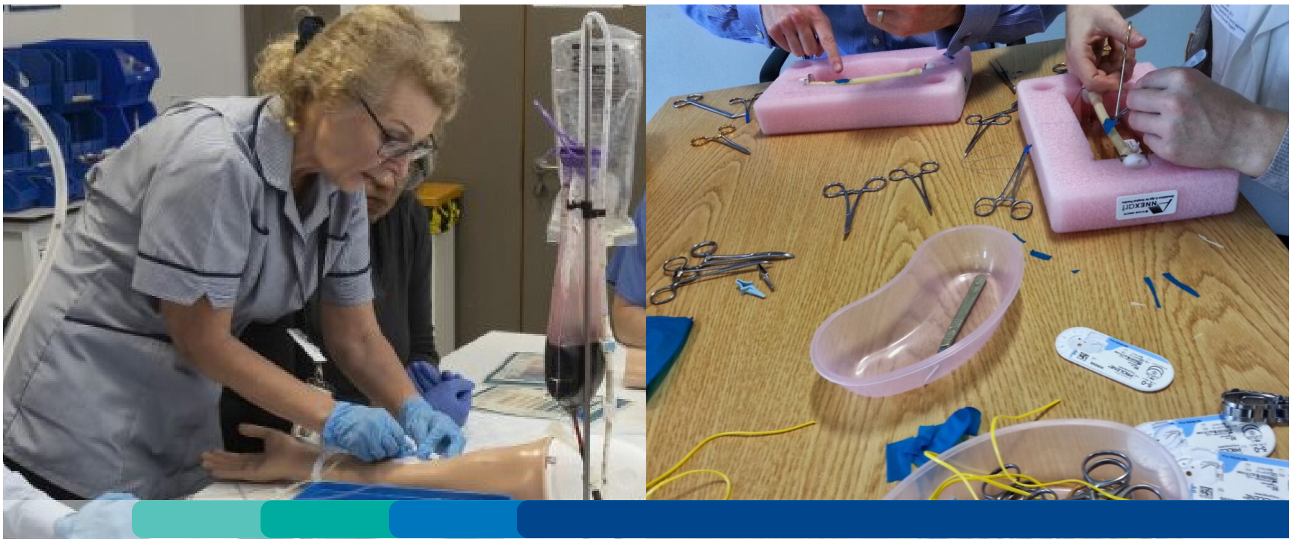
[5] Massoth, C., Röder, H., Ohlenburg, H. et al. High-fidelity is not superior to low-fidelity simulation but leads to overconfidence in medical students. BMC Med Educ 19, 29 (2019). https://doi.org/10.1186/s12909-019-1464-7

Types of Simulation

Simulation-based techniques can encompass a wide range of modalities. A brief description of each type of simulation activity as well as the limitations is described in the following section

Task Trainers

Task trainers are closely related to manikins, and can be physical replicas of a body part, a screen-based representation, or a combination of the two. These are used most often to help train specific skills or tasks that are new to the individual practitioner and are regularly focused on teaching specific medical procedures, such as venepuncture, wound care, suturing, and catheterisation. As they are simplified models, they are cost-effective and help students develop proficiency in specific clinical techniques.



Advanced Procedural Trainers

Advanced procedural trainers can be physical devices or screen-based platforms, offering a combination of technology and real-world simulation. These devices emulate the details of clinical procedures which necessitate a methodical progression of tasks for successful performance. The trainers can adjust to varying degrees of difficulty, supporting the experience according to the learner's expertise. This adaptability is useful for a user base with different experience levels, from novices who can grapple with foundational techniques to more experienced clinicians completing intricate challenges.

Many of these advanced digital trainers also support and incorporate autonomous feedback mechanisms for assessment. By integrating sensors and data analytics, these devices can offer helpful insights into a learner's performance. This feedback, both immediate and objective, fosters an environment of self-guided learning and iterative improvement.Endoscopy training modules serve as a prominent example, the spectrum of these trainers also extends to varied domains, encapsulating an array of surgical apparatuses and techniques.

Simulated/Standardised Patients and Actors

This form of simulation involves interaction between the learner(s) and another person who plays the role of the patient, a family member/carer, or a colleague. This is a powerful way to focus on training or assessment of key communication skills, such as consultations, taking consent, breaking bad news, or escalating concerns. In high-stakes assessments this involves professionals as the simulated patient (or other role) whilst at the other end of the spectrum it can involve students or staff role-playing different roles themselves. Simulated patients are used for formative activities, where they can respond with more authenticity and flexibility to course participants whereas standardised patients are used for those activities that require a degree of consistency and accuracy in behaviours (e.g. observed structured clinical examinations). A limitation of all simulation-based activities is that patient and public involvement in the design and evaluation is often limited, even in its application to learning outcomes that are directly relevant to patient experience and safety of care.

Moulage and Simulation Makeup

Moulage is the art of using makeup, special effects materials, and props to create lifelike injuries, medical conditions, or physical abnormalities. It is widely used in healthcare simulation to enhance the realism of scenarios and engage learners more effectively.

Educators can use moulage to create a wide range of simulated injuries and medical conditions, from simple cuts and bruises to complex trauma injuries or disease manifestations.

This versatility enables educators to tailor simulations to specific learning objectives and offers a cost-effective way to enhance the realism of simulations. Moulage often requires staff to attend short training courses to learn the skills, but once learnt they can be expanded upon and enhanced with practice.

Cadaveric Dissection and Wet Tissue Simulation

Many of the practical skills that healthcare professionals perform require expert instruction, repeated practice, and constructive feedback. If performed badly, clinical procedures have the potential to harm the patient, hence the need for simulation-based learning. Although advances in technology-based learning systems have helped to develop and improve skills, there remains a real need for deliberate practice using actual tissue, particularly in the sphere of surgical training.

The use of live, anaesthetised animals in learning situations is forbidden by law in the UK but there are two alternative sources of tissue: human cadavers and dead animal tissue.

Cadaveric Dissection

The use of human cadavers – once the mainstay of medical anatomy teaching – has seen a resurgence in recent years in surgical training due to advancing surgical techniques and patient expectation as well as developments in tissue preservation. The use of cadavers offers several advantages, including offering a three-dimensional structural organisation of the human body and its variations, an ability to perform complete surgical procedures and perhaps most importantly an appreciation of how tissues and structures feel.

Wet Tissue

Dead animal tissue has been widely used in surgical training in so called ‘wet lab’ settings. The major proponents of this approach have been cardiac surgeons using primarily fresh pig hearts which have a close anatomical similarity to the human heart. Most heart operations can be practised on pig hearts in a realistic and repeatable manner.

An advantage of wet lab training is that it can be established easily and regularly, allowing the repeated practice that is necessary to acquire surgical skills. Instruction, feedback, and assessment can take place in a safe environment and can be extended to the whole of the multi-professional surgical team. Several hospitals have recently established permanent wet lab facilities to encourage self-directed opportunistic learning.

Simulated Environments and In-Situ Simulation

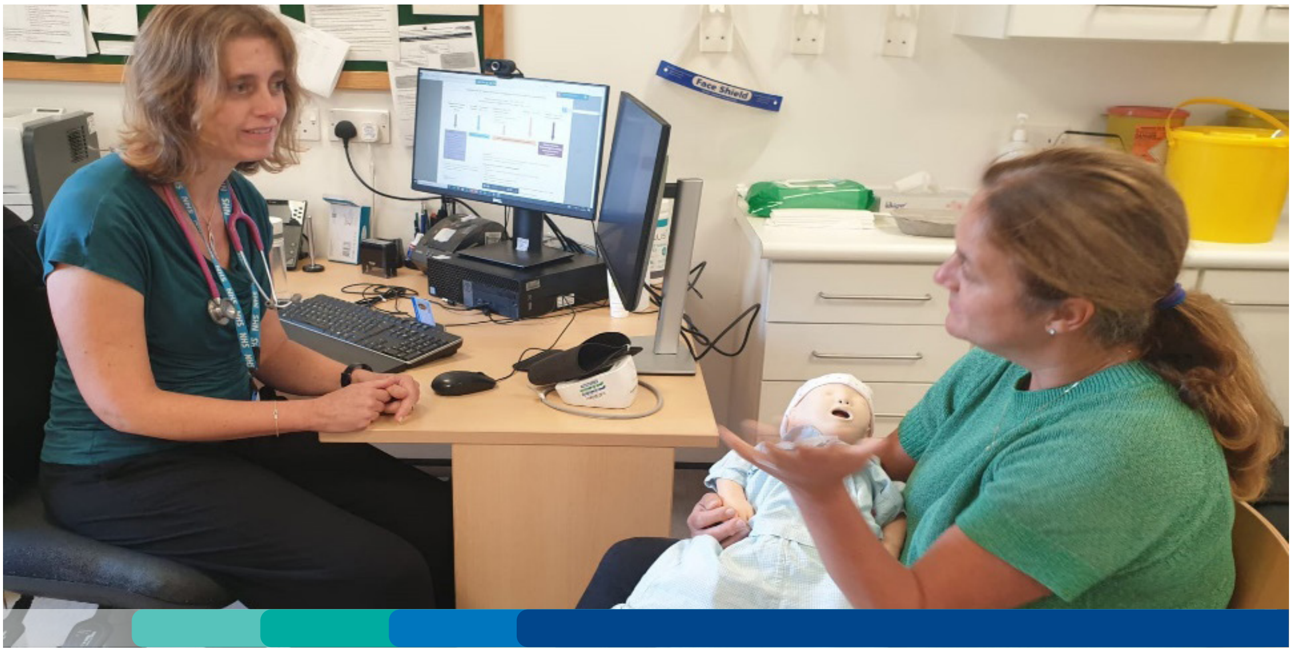
Simulated Environments

Simulated clinical environments, such as mock hospital rooms or operating theatres, provide a controlled setting for learners to practice and refine their skills. With the use of technology such as immersive screens an entire room can be transformed to simulate any environment. Simulated clinical environments, such as mock hospital rooms or operating theatres, provide a controlled setting for learners to practice and refine their skills. With the use of technology such as immersive screens an entire room can be transformed to simulate any environment.

In-Situ Simulation

In-situ simulation is actively integrated into the working clinical environment, such as a hospital ward or in general practice. This form of simulation enables individuals or more commonly, multi-professional teams, to practise a simulated scenario that reflects how it would be carried-out, producing real-life scenarios to improve reliability and patient safety in high-risk areas. This can be advantageous when seeking to rehearse professional capabilities and teamworking skills and identify specific cognitive, interpersonal, and wider work system factors that influence performance of a task or episode of care. This method can also be used to highlight latent threats or hazards that may impact patient safety and assess wider work system design features that may influence organisational performance and staff wellbeing.

There are some advantages to making use of in situ simulation instead of relying on use of simulation facilities away from the workplace, such as providing access to clinical staff directly within their work setting and using relevant equipment and other resources for their clinical roles. Some disadvantages also exist such as the need to coordinate and communicate about the activity to manage the potential disruption to ongoing clinical care and inform patients and families in case they become concerned.



In the NHS, one example of in-situ simulation is a breached-delivery childbirth simulated on a maternity ward. This would see midwives, paediatricians and other maternity staff working through the problem in real-time, building team skills and trust in the team, as well as practising the skills needed to deal with such a scenario. In-situ simulation has enabled the NHS to deliver learning experiences in a more diverse range of settings, some of which are technically challenging to reproduce in a simulation centre. These include neonatal intensive care, paediatric operating theatres, patient transfers and multiple settings and multiple teams within a scenario. Increasingly, each scenario and associated learning outcomes are targeted at either system, process and resilience or clinical and human factors.

Simulation for Interprofessional Education and Team Training

Simulation-enhanced interprofessional education (Sim-IPE) describes the use of simulation to enhance how individuals from different health and care professions can learn with, from, and about each other through a shared experience of simulation. These simulation activities are specifically designed and facilitated to help develop and master interprofessional practice competencies. This approach is often extended for qualified staff to support the development of teamworking skills and behaviours, which may be more context specific for different health and care settings and patient care pathways.

Different learning environments can be used for Sim-IPE and/or team training experiences, usually dependent on the level of experience of the learners and the needs or outcomes being addressed.

Human Factors and Simulation

Human factors, also known as ergonomics, describes the complexity of health and care work through observation and analysis of the interactions between the people, equipment, technologies, work environment, systems, and processes. Team-based simulations (often in-situ) can help detect latent threats or hazards that may underpin potential patient safety incidents, as well as highlighting the wider work system design features which influence performance of individual clinical staff and teams.

In high-risk industries outside of health and care, the use of human factors science and practice involves specialists liaising with staff from many different departments that influence how the organisation is performing. In health and care, this might take the form of simulation-based interventions involving input from colleagues in non-clinical roles or clinical support departments that are not directly patient-facing such as information technology, medical devices, procurement, estates, and human resources. Similarly, the opportunity to engage with patients, service users and carers may offer unique opportunities to use simulation to benefit delivery of safe, effective care.

Mental/Verbal Rehearsal and Serious Gaming

Anticipating and preparing for various scenarios is an intrinsic human behaviour, especially when gearing up for a specific task or operation. These preparatory mental simulations, which might be vocalised during team-based assignments, can often be guided by structured protocols like checklists or cognitive tools. These rehearsals are highly adaptable, fitting into diverse schedules and requirements with minimal dependency on additional resources.

The notion of 'serious gaming' plays a pivotal role in these mental/verbal rehearsal exercises. By introducing elements of play and strategy into real-world tasks, it allows for a more in-depth understanding and internalisation of processes. The rise of digital technology, notably smartphone applications, has further expanded the scope of these rehearsals. Such applications can provide frameworks that assist in breaking down complex decisions, offering a systematic pathway to explore outcomes and repercussions in a risk-free environment.

Beyond individual or team-based tasks, the application of this rehearsal methodology has widespread implications. In healthcare settings, for instance, it can be employed in training medical professionals for rare surgical complications or handling unexpected patient reactions.

The scalability of this approach is also important. For organisations or entities, these rehearsal strategies can be employed to simulate large-scale operations, such as organising a hospital's protocol during a pandemic outbreak, or preparing a corporation for a cybersecurity threat, the principles remain constant.

Computer-Based Simulation

Computer-based simulation may include interactive software programs that present clinical cases, quizzes, and scenarios, enabling learners to make decisions and receive feedback in a controlled setting. These are an extension of the various TEL modalities including elearning.

Limitations are that these activities can easily be perceived as costly either in design, licences, delivery overheads or related to time away from clinical service for learners and faculty.

Extended Reality (XR) and Immersive Technologies

Extended Reality (XR) technologies are immersive environments that can replicate medical settings or scenarios. Learners can interact with virtual patients, equipment, and environments to practice clinical skills and decision-making.

An increasing number of institutions and professionals are harnessing the capabilities of tools such as virtual reality, which is accessible through specialised headsets or multi-screen projected setups. The more entry-level medium of VR 360-degree video provides opportunities for quick scenario recording and playback as well as more complex interactive layered content, which can be harnessed for decision trees and story branching in scenarios. This medium has seen adoption from educational and simulation teams creating their own content. Augmented reality bridges the gap between theoretical knowledge and practical application by overlaying data on top of the real world, providing an enhanced learning experience that suggests digital interaction and engagement.

However, some limitations associated with these types of approaches are that they are often reliant on faculty and/or technical support that may not be readily available due to other clinical or educational commitments and there also needs to be an adequate IT network and infrastructure.

There are three main types of XR described below, as well as 360-degree video which can be displayed on a computer screen, mobile device, or virtual reality headset.

Virtual Reality

Virtual Reality (VR) is a digital technology that creates a three-dimensional, computer-generated environment. In this environment, an individual can not only explore but also interact, making them an integral part of the virtual world. This total immersion replaces the tangible, real world with a simulated one, allowing users to experience scenarios and settings as if they were there virtually.

The hardware used for VR is broadly categorised into two types:

- **Stand Alone:** These devices are self-sufficient and don't require any external connections or devices to operate. They offer a wire-free experience, making movement more fluid.
- **Tethered:** These headsets are connected to a PC through a cable. While this can sometimes limit mobility, they often provide higher processing power and graphic quality due to the capabilities of the connected PC.

The VR market has a variety of headsets available, each varying in technical ability and quality of the experience. From basic models offering straightforward VR experiences to high-end versions providing intricate details and realism, there's a range to cater to different needs and budgets.

360-Degree Video

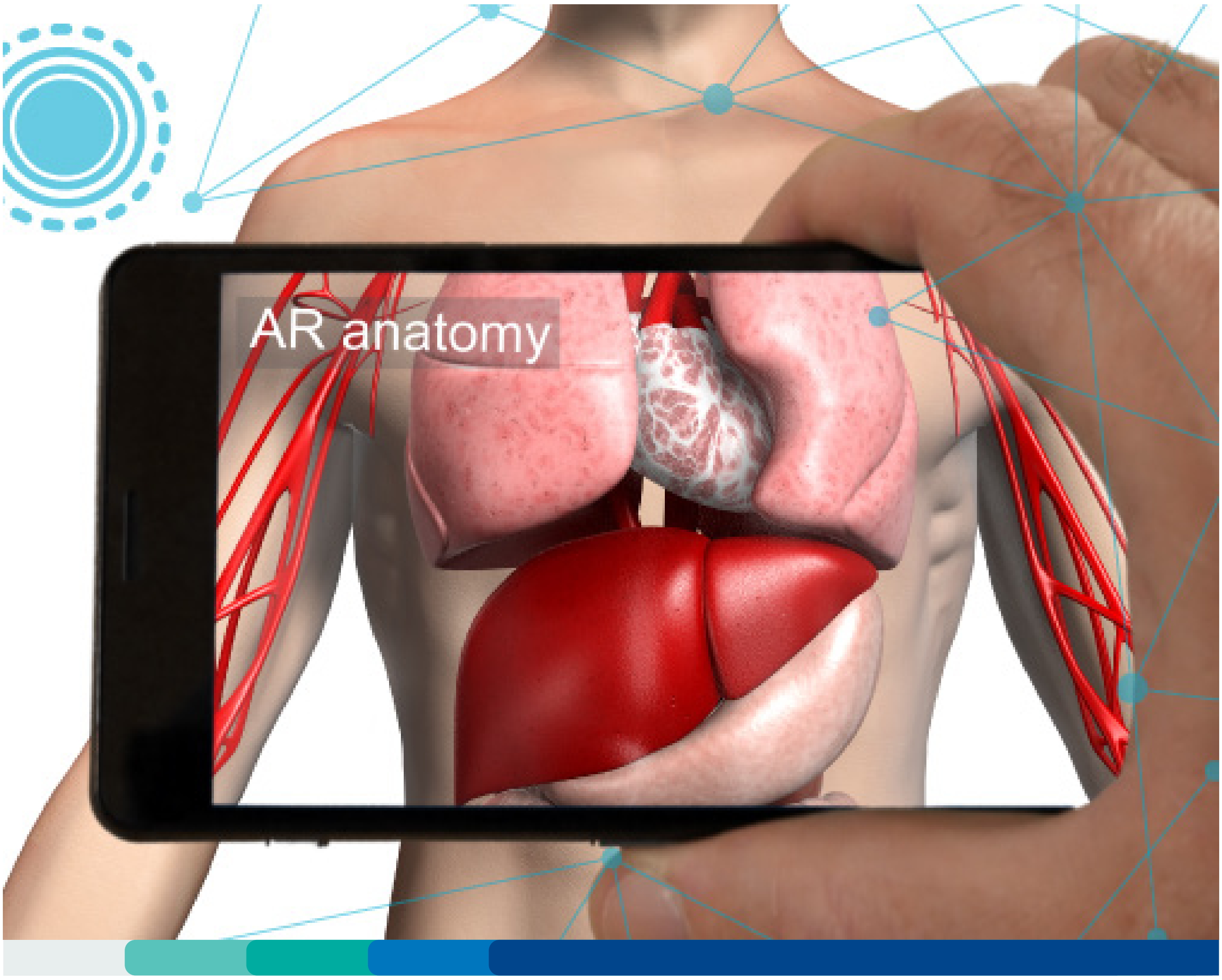
360-degree videos, often termed immersive or spherical videos, capture every direction simultaneously, providing a full, round view of the environment. In medical simulation, this offers students and professionals an authentic virtual glimpse into procedures, scenarios, or environments like operating theatres or patient interactions. When played back using a Virtual Reality (VR) headset, viewers are transported into the medical setting, allowing them to look around and interact, crucial for grasping complex procedures. Interactivity is enhanced with VR controllers or gaze-based actions. On standard flat screens, users can control the viewing direction, akin to navigating a panoramic image.

In the context of simulation, where realistic training is paramount but can be hindered by logistical and ethical challenges, 360-degree video serves as an ideal introduction to immersive technology. It offers a cost-effective and easily accessible means for students and professionals to step into realistic medical scenarios. Whether it's observing a complex surgical procedure, navigating a busy hospital ward, or interacting with a virtual patient, these videos can bridge the gap between theory and practice without the constraints of a real-life environment.

Augmented Reality

Augmented Reality (AR) is a digital technology that overlays computer-generated information, such as graphics, sounds, or other data, onto our view of the real world. Unlike Virtual Reality, which immerses users in a fully virtual environment, AR augments or enhances the user's actual surroundings.

The primary interface for AR has traditionally been through devices like smartphones or tablets. Using the device's camera, the real-world view is captured and then augmented with additional layers of digital content, typically in real-time. In the context of medical and healthcare simulation, an example would be a medical student learning about complex surgeries. Using an AR application, they could point their device towards a manikin or even a printed image of human anatomy. The AR system could then overlay a 3D model, pointing out key structures. In addition to smartphones and tablets, AR is now being integrated into wearables like smart glasses, head-up displays in vehicles, and even interactive surfaces.

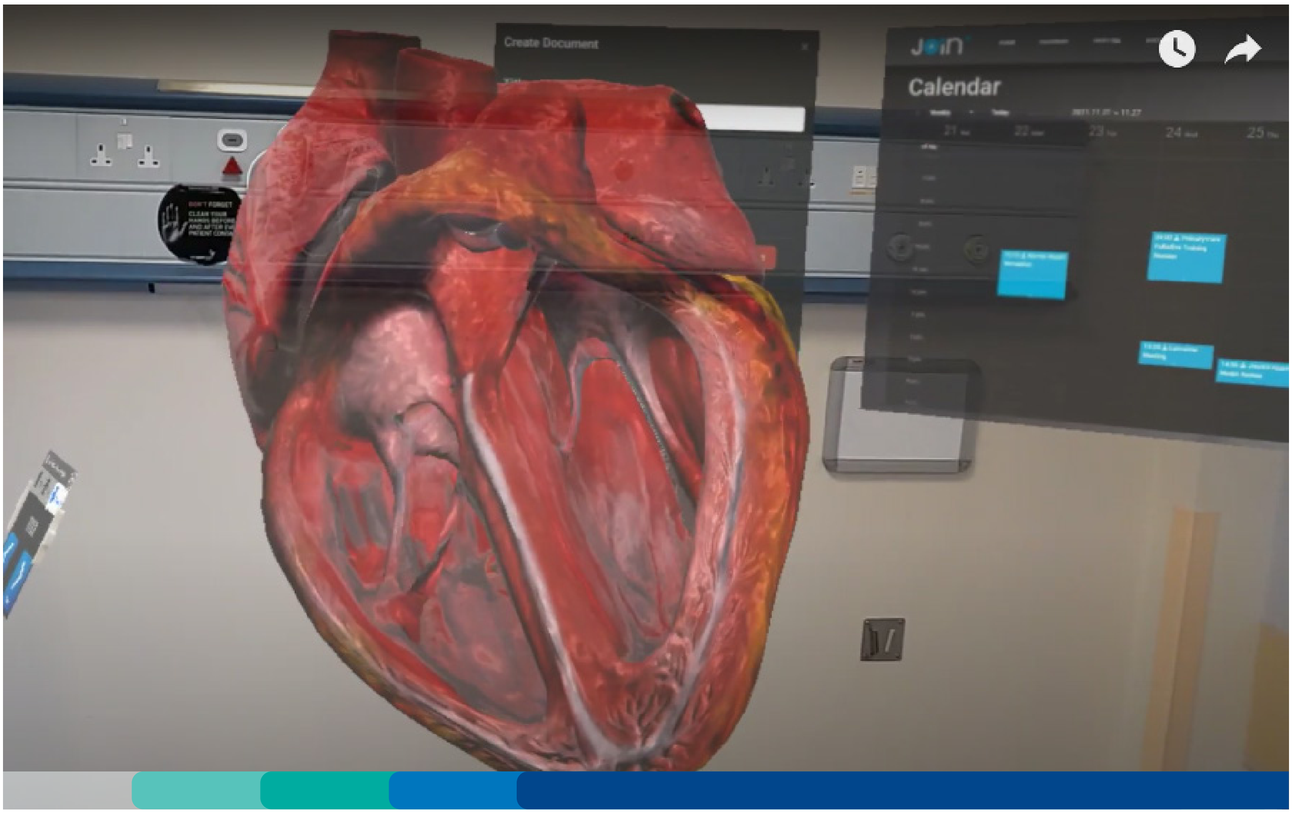


Mixed Reality

Mixed Reality (MR) is a blend of the physical and digital worlds, bridging the gap between Augmented Reality (AR) and Virtual Reality (VR). While VR immerses users in a completely virtual environment and AR overlays digital content onto the real world, MR combines the best of both, creating an environment where real-world and digital objects coexist and interact in real-time.

Mixed Reality often relies on a head-mounted display (HMD). However, unlike the opaque screens of many VR devices, MR HMDs are more akin to see-through glasses. This design allows users to remain connected to their actual surroundings while also viewing and interacting with digital content superimposed on their environment.

As an example, wearing an MR headset, a user could see a digital holographic heart floating in their room. Not only can they walk around it, viewing it from all angles as they would a physical object, but they can also reach out and 'touch' it, manipulate its size, or even dissect it using hand gestures or tools. MR brings a realm where the boundaries between the tangible and virtual blur, offering unparalleled opportunities for immersive experiences.



Haptic Simulation

Haptic technologies recreate the sense of touch using forces, vibrations, and motion. This enables an additional sense of reality when conducting a simulated clinical practice, allowing the learner to feel the potential pressure, or resistance that would be experienced in a real-life situation. This is particularly useful when combined with simulation manikins and virtual reality to promote an increased sense of reality and a suspension of disbelief.

The principal objective of haptic feedback is the merging of skills acquisition with real-time feedback. Conventionally, face-to-face discussions with the instructor occur after the procedure due to time constrains and high learner: teacher ratios. At present, simulation tools provide a valuable supplementary tool to augment, rather than replace, traditional teaching and assessment methods. However, emerging haptic technologies have an important role in the training and assessment of the healthcare workforce and there is widespread use within the early years of postgraduate medical and dental training programmes. The primary focus of the current haptic simulations is the development of patient-specific treatment exercises to enhance patient safety and to support learners to practise in a safe environment.