What Healthcare Educators know about Extended Reality (XR)

A Research Programme to understand XR implementation within London

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What Healthcare Educators know about Extended Reality (XR)

The Executive Summary of research to describe the understanding and uptake of XR within London

Extended reality (XR), including Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) are emerging as new training modalities within healthcare. To guide Health Education England's Technology Enhance Learning Strategy, UCLPartners commissioned King's College London to undertake a rapid literature review and an in-depth interview study of experienced simulation educators. The literature review and research addressed the following questions:

1. Which healthcare specialities have the strongest evidence for XR implementation?
2. How widely is XR used in a large healthcare system such as London?
3. What are the facilitators and barriers for simulation practitioners adopting XR technology?

Literature Review

The literature review identified 141 systematic literature reviews (SLRs) of XR in healthcare education from six major educational and medical databases. Following shortlisting, 24 SLRs were included in the final review. There is evidence for the effectiveness of XR technologies in improving skills (predominantly procedural skills in surgery and clinical skills in nursing), knowledge (predominantly of anatomical structures via a 3D visualisation), and attitudes (including self-efficacy, confidence and stress-resilience). Key advantages of XR technologies as detailed in the literature include: increased learning mobility; repeated practise for mastery of clinical or procedural skills without adverse patient impact; immersive learning opportunities for complex medical contexts; self-directed learning; ability to set quality and performance standards; and preparing learners for technologically advanced healthcare practice. VR and AR were perceived as an engaging and motivating learning modality, and were mainly advocated as training enhancement methods to compliment, rather than replace, traditional education.

Interview study of experienced educators

Data was collected from semi-structured telephone interviews with 16 simulation practitioners from 13 NHS Trusts (12 from within the London Simulation Network) including simulation and medical education leads, simulation technicians, educators and simulation centre managers.

Implementation of XR within the LSN is limited and pioneering at present. Only seven of 13 NHS Trusts interviewed reported experience of XR (in any form). Multiple benefits from XR for learners, educators and faculty were conceptualised by study participants. Barriers and facilitators of XR implementation are summarised in the Fig 1,in the order of their prevalence as indicated by the interviewed staff.

Barriers and Faciliators of XR Implementation	
Barriers	**Facilitators**
High cost	Comprehension of the modality
Poor quality software	Buy in from colleagues + exec
Staff attitutes	Networking opportunties
Limited evidence of effectiveness	Central coordination of XR procurement
IT systems	A skilled technical team
Limited workforce support for XR modalities	

Barriers and Facilitators of XR Implementation (Fig. 1)

Recommendations

1. Set Realistic Expectations for XR Technologies supported by evidence of their effectiveness, required human and infrastructure resources and additional funding for hardware and software purchase and update.

2. Facilitate Access to XR Technologies by providing colleagues with the opportunities to trial and experiment with them, as well as share experiences (both successful and otherwise) and learn from others through networking opportunities.

3. Develop and Fund Strategic Research about XR Technologies to focus on applications and contexts beyond procedural skills, and the mechanisms by which these technologies support learning. There is a clear opportunity for research that both contributes to the wider knowledge base while supporting the strategic needs of healthcare educators in the NHS.

4. Financially Support the Development and Acquisition of XR Technologies for the NHS Context to address the high cost of XR hardware and low quality of medical software.

5. Regional and National Strategies are Needed for XR Technologies adoption to achieve an equitable training experience within regions; focusing on surgical and procedural skills development would be a low-risk application. A second, exploratory application of XR could be in theoretical knowledge acquisition, as a more engaging and motivating modality.

6. Continue to Address Digital Readiness by promoting and supporting the implementation of the *TEL Readiness Assessment Matrix* to support educators and organisations to identify suitable technologies for local adoption.

7. Faculty Development is Central to XR Adoption and should initially focus on understanding the technology and terminology (both theoretical and hands on experience).

What Healthcare Educators know about Extended Reality (XR)

A seven page summary of research to describe the understanding and uptake of XR within London

Background to this research

Extended reality (XR), including Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) are emerging as new training modalities within healthcare. Their potential was outlined within the Topol Review and Health Education England have committed programmes of work to test VR technologies and develop best practice guidance. Within this mission field, UCLPartners, with Yorkshire and Humber AHSN and North East North Cumbria AHSN were commissioned to a) develop the XR industry pipeline and market signalling, b) identify real world evidence in the form of case studies and c) to develop a plan to support the workforce to adopt XR by sampling the status of XR implementation in healthcare education and their current capabilities to make use of the technology.

This report summarises the outputs of Part C – by answering the following questions:

1. Which healthcare specialities have the strongest evidence for XR implementation?
2. How widely is XR used in a large healthcare system such as London?
3. What are the facilitators and barriers for simulation practitioners adopting XR technology?

What we did

UCLPartners commissioned King's College London as academic partners to support this programme. They carried out a rapid review of existing literature on immersive technologies in support of education for healthcare and an in-depth interview study of experienced simulation educators.

Literature Review

The literature review identified 141 systematic literature reviews (SLRs) of XR technologies application in healthcare education from six major educational and medical databases. Following shortlisting, 24 SLRs were included falling into 3 categories. (Full search criteria available on request[1]):

- **AR** technologies were discussed in seven reviews (N=7), covering the following areas: surgical education and training (1, 2); neurosurgery and neuronavigation (3, 4); medical education (5); dentistry (6) and AR applications in healthcare beyond surgery (7).
- Immersive VR (**I-VR**) were discussed in nine reviews (N=9); including three reviews of I-VR in nursing education (8-10); as well as training in surgery (11), plastic surgery (12)

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- and oral maxillofacial surgery (13); I-VR as a pedagogical tool in education (14) and medical practice (15); and in non-technical skills training (16).
- **XR** (VR, AR and MR) were reviewed in eight reviews (N=8), covering neurosurgery (17-20), ophthalmology (21-23) and medical education in general (24).

Interview study of experienced educators

Data was collected from semi-structured telephone interviews with simulation practitioners. Data was anonymised and thematically analysed using a framework derived from the interview topic guide. The interviews explored an individual's understanding of XR, the local uptake of XR, experiences of XR and the benefits and barriers of XR implementation. (Interview topic guide is available on request[1]).

16 simulation practitioners were interviewed from 13 NHS Trusts (12 from within the London Simulation Network) including simulation and medical education leads, simulation technicians, educators, managers and similar associated roles.

What we learned from the literature review

There are a large number of publications related to XR technologies in healthcare education of various degrees of rigor and quality. Most publications are from USA and well-developed countries.

Data on the effectiveness of XR technologies in postgraduate health education is dominated by the evidence from surgical specialities and is mainly related to procedural and psychomotor skills development. There is also evidence for the effectiveness of XR technologies in improving knowledge (anatomical 3D models) and attitudes (self-efficacy and stress resilience).

Key advantages of XR technologies as detailed in the literature include: increased learning mobility; repeated practise for mastery of clinical or procedural skills without adverse patient impact; immersive learning opportunities for complex medical contexts; self-directed learning; ability to set quality and performance standards; and preparing learners for technologically advanced healthcare practice.

XR technologies were perceived as an engaging and motivating learning modality and are mainly advocated as training enhancement methods to compliment traditional education and not as a replacement for existing methods.

Augmented reality (AR)

AR is used to understand spatial relationships and construct 3D mental models, often anatomical models. It has been shown to assist in the acquisition of cognitive psychomotor abilities, to prolong learning retention, experience student-centred motivation and allows flexibility to learn anytime and anywhere and at the learner's pace and scale. (The authors observe that "anytime and anywhere" is circumscribed by the accessibility of head-mounted displays (HMDs)).

AR and surgical training

As surgery is a visual and tactile speciality, it lends itself well to the AR modality. Within reviewed articles, it was most commonly used to train motor skills or as an intraoperative navigation guide.

Surgical disciplines that were reviewed included neurosurgery, colorectal, gynaecological, neurological, orthopaedic, plastics, trauma, urological and vascular surgery, as well as basic surgical skills. For motor skills development AR offers a better user experience than VR as it provides real tactile feedback, improved haptics and lack of reliance on complex digital graphics that are often unrealistic. Within dentistry, users react positively to the experience reporting improved precision of operations.

AR beyond surgical training

Overall, evidence of AR applications beyond surgery and dentistry is less well developed; low quality and heterogeneous study designs were acknowledged.

Virtual reality (VR)

VR is used in two forms, with a HMD or via a desktop. There is no consensus in the literature with regards to the definition of VR and data from interactive immersive VR with HMD (I-VR) cannot always be isolated from desktop-VR (D-VR).

Many studies identified I-VR with HMD to be advantageous over traditional methodologies in teaching procedural skills (often citing surgical and dental procedures). Unlike AR, literature describes its use as both a training tool *and* as an assessment tool. VR allows repetition of complex and demanding tasks in a safe environment . VR can also provide alternative environments to facilitate situated learning through a variety of virtual contexts that give the user a sense of presence and thus the ability to learn in a unique context.

VR and surgical training

Within surgery (including neurosurgery), there is growing evidence for the effectiveness of I-VR with the potential to supplement traditional training modalities. Main advantages include rich contextual experience, reduced training time, benchmarking performance and tracking training progress.

VR beyond surgical training

Within nursing, virtual worlds were effective in improving theoretical knowledge and psychomotor outcomes, as well as usability outcomes (including student motivation). It has a favourable time-cost-effectiveness as compared to manikin -based simulations and in person lectures. Effective use of I-VR in emergency preparedness through exposure to realistic and highly stressful emergency scenarios led to increased self-efficacy, self-confidence and stress resilience.

Only one review of VR effectiveness in non-technical skills training for healthcare professionals was identified, with limited evidence for I-VR. The non-technical skills addressed in VR simulations included teamwork, communication and situational awareness.

Limitations of VR

The limitations of VR were acknowledged in the cost of the necessary hardware with high processing speeds and expensive software licenses. The VR market fragmentation is challenging to navigate. Effort and eye fatigue limit session length and motion-sickness if often reported.

What we learned from interviewing simulation practitioners

Understanding and Uptake of XR

Study participants described their understanding of XR, with most more familiar with VR and AR (over XR). AR definitions had some consistency but VR definitions were less consistent, most were associated with an HMD and computer generated images (CGI). Only one participant described a distinction between 360 video content and a CGI environment.

The potential of I-VR to enhance learning experiences and widen access to education was conceptualised by study participants but buy-in from senior decision makers and wider awareness of the technology limits implementation. Resources for XR implementation are very limited and most trusts are working experimentally and opportunistically to test XR in different teaching contexts.

There is limited implementation of XR technologies within London: interviewees from six of 13 trusts within the sample indicated no experience at all. Of the seven who have some experience, two centres participation is via HEE XR hub pilots. Experience with AR/VR technologies in teaching highly complex procedural skills (e.g. in surgery) has been in place in some trusts, however overall experience with immersive VR (I-VR) technologies (via a HMD) is rather limited and is only emerging.

The Perceived Benefits of XR

The main benefits to **the learner** were perceived in the control of the pace, location and timing of training and adjust these to suit their needs. There is a perception that a wide range of knowledge and skills could be taught using VR, particularly using its ability to offer complex environments or situations that are difficult to replicate by using traditional teaching methods.

The benefits to **educators and employers** were perceived to be in relation to training faculty and room capacity although it was acknowledged that learners require guidance when first using a VR environment and it is necessary to pump-prime this work: investing in the technology and technology knowledgeable staff, the development of scenarios and faculty development to use the modality to good effect.

The Barriers and Facilitators of XR Implementation

Barriers and Faciliators of XR Implementation	
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Barriers and Facilitators of XR Implementation (Fig. 1)

Several themes which were identified as barriers were described in their inverted form as facilitators. For instance, staff attitudes can be a barrier but buy-in from colleagues and executive support are facilitative. Other pairings are highlighted with colour in the graphic below. (Fig1)

Sometimes, relationships between barriers and facilitators were drawn, with exposure to XR being identified as the antidote to resistance.

Barriers to XR Implementation

The most prevalent factors identified as barriers for XR technologies implementation from interviews included (in the order of their prevalence): High cost, Poor quality software (with limited off the shelf scenarios), Staff attitudes and a resistance to change, Limited workforce to support XR modalities, IT systems and The Limited evidence of the effectiveness of XR modalities.

Educators believed in the potential of XR, but many suggesting it is insufficiently developed; software is perceived as of poor quality and off-the-shelf scenario libraries offer limited options. Both hardware and software were identified as being expensive and challenging to fund.

Slow IT approvals for software and equipment utilisation was a source of delay. Limited resources for healthcare education and the lack of technically skilled staff to drive the implementation of XR technologies were another barrier; educational innovations are often driven by enthusiastic volunteers.

Facilitators of Implementation

Strong themes were identified for the facilitation of XR uptake and implementation. These were: Comprehension of the modality, Buy in from colleagues and executive, Networking opportunities, Central coordination of XR procurement, and a Skilled technical team.

Networking, learning from others, sharing experience and resources was a prominent theme facilitating the uptake of XR technologies, helping participants develop the understanding of this new technology. Interviewees praised the LSN and HEE for providing practical assistance with networking and hands-on experience via technologies road shows and equipment loan schemes.

Central coordination of XR procurement could prevent fragmented and dispersed implementation of XR technologies in healthcare education, and would help to ensure standards as well as equality of opportunities to engage with these new technologies.

Interview participants discussed, at some length, the importance of investing in knowledgeable, technology-enthusiasts. All technicians involved in this study shared their personal experiences with I-VR technologies and enthusiasm about XR technologies as a great educational modality in general.

Recommendations

Based on the findings from literature and interviews with London based simulation practitioners, the authors make the following suggestion to those commissioning healthcare education and those supporting the uptake of XR:

1. Set Realistic Expectations for XR Technologies

XR is viewed neither by academics, not educators as a replacement for any existing training modality. There is an expectation that XR technologies will reduce space constraints required for simulation and clinical skills labs and will require fewer faculty to support learners. This assumption is aired widely in the publicity and marketing of XR. In reality, it is used alongside existing modalities and it will pressurise other parts of the education system (at least during early implementation stages) – namely learning technologists and technicians, IT systems and there is a financial outlay associated with hardware and software.

2. Facilitate Access to XR Technologies

Due to limited familiarity with XR technologies amongst NHS colleagues, it is important to facilitate access to these technologies, and support colleagues to trial and experiment with them. This must be further supported through opportunities for networking to share experiences (both successful and otherwise) and learning from others.

3. Develop and Fund Strategic Research about XR Technologies

Due to the discrepancy between *perceived benefits* of XR technologies as reported by trained simulation and the *existing evidence* of effectiveness, further research should focus on applications and contexts beyond procedural skills, as well as the mechanisms by which these technologies support learning. Further evidence is needed for XR technologies effectiveness in developing affective and non-technical skills. There is a clear opportunity for research that both contributes to the wider knowledge base while supporting the strategic needs of healthcare educators in the NHS.

4. Financially Support the Development and Acquisition of XR Technologies for the NHS Context

The cost of XR hardware and software was identified as the highest barrier by study participants for the technologies' uptake and implementation. Economic analysis of VR technologies would be helpful to address cost-related concerns. Further consideration on to how to improve the quality of medical software used in XR applications, particular in I-VR, and address unique contextual and curriculum requirements of the NHS is also needed.

5. Regional and National Strategies are Needed for XR Technologies

To achieve an equitable training experience within regions, regional strategies for XR adoption should be developed. The evidence for XR is most extensive within surgical and procedural skills so to focus here would be a low-risk application. A second, exploratory application could be considered, drawing on the evidence in support of XR in theoretical knowledge acquisition, as a more engaging and motivating modality.

6. Continue to address digital readiness

Given the low digital literacy levels in relation to XR technology, HEE should continue to promote and support implementation of the *TEL Readiness Assessment Matrix* to support educators and organisations to identify suitable technology for local adoption.

7. Faculty Development is Central to XR Adoption

Educators need support, knowledge, and opportunities to learn about XR and share their successes and innovation with colleagues. Faculty development remains crucial. This should initially focus on understanding the technology and terminology (both theoretical and hands on experience). A quick reference guide to different elements of XR is necessary (types of HMD/CGI vs 360/interactive vs immersive/haptics and hand controls).

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Authorship:

The authoring team would be delighted to discuss this work further.

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