

EXPLORING THE UTILITY OF EXTENDED REALITY IN RURAL MEDICAL EDUCATION: A PROGRAMMATIC RESEARCH SYNTHESIS

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Abstract

Extended reality (XR), including virtual reality (VR), mixed reality (MR), and 360° video, has emerged as a promising approach for enhancing simulation-based medical education (SBME), particularly in rural and distributed healthcare settings where access to training is limited. This paper reports on a programmatic research synthesis to integrate findings from a series of related studies examining the development, implementation, and evaluation of XR technologies for neonatal resuscitation and rural healthcare education. The synthesis included five studies conducted within a coordinated research program using complementary qualitative, quantitative, and development methodologies. Participants across studies included physicians, nurses, respiratory therapists, and allied health professionals. Data sources included interviews, surveys, pre- and post-tests, performance assessments, and observational data. Four overarching themes emerged from the synthesis. XR technologies demonstrated strong educational value, with VR simulation improving confidence, perceived usefulness, and performance in neonatal resuscitation skills. XR environments enhanced immersion and experiential learning, with participants reporting strong presence and engagement. XR technologies improved access to training, particularly for rural healthcare providers, by reducing travel requirements and supporting flexible, repeatable learning opportunities. Implementation challenges included technical limitations, infrastructure requirements, and the absence of tactile feedback. Overall, findings suggest that XR technologies offer a promising complementary modality for SBME and continuing professional development (CPD). XR-based approaches may enhance access to training, improve learner engagement, and support skill development in rural healthcare settings. Further research is needed to examine long-term educational outcomes and implementation strategies across diverse healthcare environments.

Keywords: *Extended Reality (XR), Head-Mounted Display (HMD), Simulation-Based Medical Education (SBME), medical education, rural education.*

1. Introduction

The sustainability of rural healthcare systems is increasingly threatened by shortages of healthcare providers and difficulties in recruiting and retaining physicians in rural communities (Asghari et al., 2020; World Health Organization, 2010). Rural populations also face poorer health outcomes and greater healthcare needs compared with urban populations, further increasing the demand for well-trained rural healthcare professionals (Curran & Rourke, 2004; Welton et al., 2025). Healthcare professionals working in rural and remote environments face unique challenges in managing diverse clinical presentations while maintaining competence in procedural skills that may be used infrequently (Curran & Rourke, 2004; Curran et al., 2010). In this context, ongoing access to continuing professional development (CPD) is essential for delivering safe and effective care, especially given the broad scope of practice required in rural settings.

CPD includes the various educational and developmental activities healthcare providers undertake to maintain and improve their knowledge, skills, performance, and relationships in healthcare (Kitto et al., 2013; Shannon, 2003). For many regulated healthcare providers worldwide, CPD participation is mandatory during the lengthy post-licensure period of their careers. It is seen as a crucial way to stay current with evidence-based practices in their field and maintain clinical skills. Evidence shows that healthcare providers who participate in formal CPD activities tend to deliver higher-quality care than those who do not (Al-Ismail et al., 2023; Kitto et al., 2013). However, access to CPD is a key factor affecting recruitment,

retention, and professional satisfaction among rural healthcare providers. Geographic isolation, travel requirements, and limited educational opportunities create significant barriers to CPD participation (Curran et al., 2006; Curran et al., 2010). These barriers underscore the importance of innovative educational solutions to help rural healthcare providers maintain their competencies.

Simulation-based medical education (SBME) modalities have been shown to effectively support clinical skill development (Elendu et al., 2024). However, simulation centres are usually located in urban areas, which limits access for practitioners in rural regions. Extended reality (XR), including virtual reality (VR), augmented reality (AR), and mixed reality (MR), offers engaging learning environments that may help address these challenges (Curran et al., 2022). XR technologies enable learners to participate in simulation-based training without travelling to centralized facilities, making them especially relevant for rural and distributed education contexts. They provide immersive learning environments that replicate clinical scenarios, allow repeated practice, and offer flexible training opportunities that can be delivered across geographically dispersed locations. Given these benefits, XR is particularly well-suited to rural healthcare education because it reduces travel requirements and supports distributed learning.

This paper provides a synthesis of a research program examining the effectiveness, perceived educational value, and feasibility of XR to improve CPD and training in rural medical education.

2. Methods

This study used a programmatic research synthesis to summarize and combine findings from a series of related studies examining the development, implementation, and evaluation of XR technologies for neonatal resuscitation and rural healthcare education. Programmatic research synthesis involves combining findings across a coherent body of research to generate wider insights beyond individual studies. The included studies were conducted between 2000 and 2026 and employed qualitative, quantitative, and mixed-methods approaches. Study findings were reviewed and compared to identify common themes and overarching insights. This approach enables integrating findings across studies to develop a broader understanding beyond individual investigations.

2.1. Context

Memorial University’s Faculty of Medicine has a longstanding international reputation for leadership in rural medical education, influenced by Newfoundland and Labrador’s geography and a strong social accountability mandate. From its early years, the faculty adopted a distributed, community-based education model, embedding learners and faculty across rural and regional sites. Memorial is also a Canadian pioneer in telemedicine and tele-education, establishing one of the country’s earliest telemedicine programs and tele-education networks to connect remote communities with clinical expertise and educational resources. These innovations have made Memorial an early and enduring leader in combining rural training with technology-enabled education and care.

2.2. Included studies

The synthesis included five studies conducted as part of a coordinated research program by members of the research team (Table 1). These studies employ complementary methodological approaches to examine XR development, evaluation, and implementation in healthcare education.

Table 1. Programmatic Research Studies.

Study	Purpose	Design	Participants	XR Modality	Data Collection	Key Focus
Curran et al. (2022)	Explore healthcare providers’ experiences with 360° VR for resuscitation training	Qualitative phenomenological study	Physicians, nurses, respiratory therapists (N=36)	360° VR video	Focus groups, interviews	User experience and perceived educational value
Aydin et al. (2025a)	Develop VR simulation for neonatal resuscitation training	Development study	Healthcare providers and learners	Virtual Reality (VR)	Usability testing, questionnaires	Simulation design and development
Aydin et al. (2025b)	Compare VR simulation and 360° video for training outcomes	Randomized crossover study	NRP providers (N=30)	VR and 360° video	Pre/post tests, surveys, performance assessment	Learning outcomes and confidence

Study	Purpose	Design	Participants	XR Modality	Data Collection	Key Focus
Attia et al. (2025)	Develop mixed reality simulation for neonatal resuscitation	Development study	Healthcare providers and learners	Mixed Reality (MR)	Usability testing, observational feedback	Simulation development and feasibility
Curran et al. (2026)	Examine adoption of XR in rural medical education	Interpretive descriptive case study	Rural healthcare providers (N=21)	VR, MR, 360° video	Interviews, thematic analysis	Implementation and adoption

2.3. Participants, data sources and synthesis approach

Across studies, participants included physicians, nurses, respiratory therapists, and allied health professionals. Data sources comprised interviews, focus groups, surveys, pre- and post-tests, performance assessments, and observational data collected from simulation labs, healthcare facilities, and rural teaching sites. Narrative synthesis was conducted to identify themes across studies (Popay et al., 2006).

3. Results

The programmatic research synthesis identified four main themes across the included studies: educational value and learning effectiveness; immersion and experiential learning; enhanced access to training and rural education benefits; and implementation considerations and limitations.

3.1. Educational value and learning effectiveness

Across studies, XR technologies were consistently seen as valuable educational tools. In a randomized crossover study comparing VR simulation and 360° video, both methods received positive feedback; however, VR simulation led to significantly higher perceived usefulness, greater confidence in neonatal resuscitation skills, and better performance on positive-pressure ventilation (PPV) tasks. Participants who experienced VR showed improved mask placement and newborn response evaluation, with blinded assessments indicating notably better PPV performance after VR training (Aydin et al., 2025b). Likewise, the VR simulation development study reported that participants found the VR environment helpful for learning and skill development, emphasizing its safety, interactivity, and realism. Participants highlighted the benefits of hands-on learning and opportunities for repeated practice (Aydin et al., 2025a). The mixed reality (MR) development study also identified the potential for XR technologies to improve skill acquisition and retention through immersive, interactive learning environments that enable healthcare providers to practice neonatal resuscitation procedures safely and repeatedly, while allowing for tactile feedback (Attia et al., 2025).

3.2. Immersion and experiential learning

A consistent finding across studies is the importance of immersion and experiential learning. Participants in the phenomenological study of 360° VR videos reported enhanced immersion, a strong sense of presence, and increased learner engagement when using VR headsets. Participants also noted that XR technologies created realistic learning environments that supported experiential learning (Curran et al., 2022). Likewise, participants in the comparative XR study reported a significantly greater sense of presence in VR simulations than in 360° videos, reinforcing the value of interactivity and immersion in XR-based learning environments (Aydin et al., 2025b). Development studies further highlighted the immersive nature of XR simulations, observing that interactive environments and realistic clinical scenarios boosted learner engagement and facilitated experiential learning (Attia et al., 2025; Aydin et al., 2025a).

3.3. Access to training and rural education benefits

The interpretive descriptive case study of rural healthcare settings identified enhanced access to training as a key advantage of XR technologies. Participants noted that XR reduced travel needs, improved access to simulation training, and supported self-directed learning in rural and dispersed environments. XR technologies were seen as especially beneficial for high-acuity, low-occurrence (HALO) clinical scenarios and refresher training (Curran et al., 2026). Similarly, the phenomenological study found that 360° VR video provided a portable, standardized way to deliver training across different locations, supporting rural healthcare education and distributed learning (Curran et al., 2022). Across the studies, XR technologies were regarded as complementary to traditional simulation-based education and as useful tools for expanding access to CPD and refresher courses.

3.4. Implementation considerations and limitations

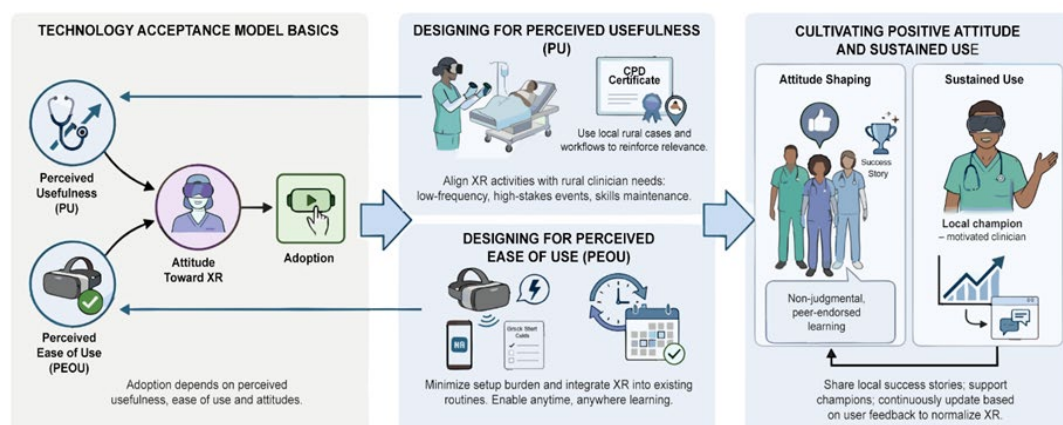
Despite the positive findings, several implementation challenges were identified across studies. Participants reported technical limitations, including hardware constraints, vision and usability challenges, and the need for improved realism and interactivity (Aydin et al., 2025a). In rural settings, participants also identified issues related to technical support, costs, and infrastructure requirements. Additionally, the lack of tactile feedback and the learning curves associated with XR technologies were noted as potential barriers to implementation (Curran et al., 2026). Participants in the phenomenological study suggested enhancements in video quality, interactivity, and realism, further highlighting areas for future development (Curran et al., 2022).

4. Discussion and conclusions

Several limitations should be considered when interpreting these findings. First, studies included in this synthesis were conducted within a single research program and geographic region, which may restrict their generalizability. Some of the studies also focused on early-stage development and implementation of XR technologies, and long-term educational outcomes were not assessed. Variations in study designs and participant groups may also hinder direct comparisons across studies. Nonetheless, the findings from this synthesis suggest that XR technologies hold significant potential to improve healthcare education, especially in rural and remote settings. Future research should explore long-term learning outcomes, cost-effectiveness, and implementation strategies across diverse healthcare environments. Additionally, further investigation of multimodal XR approaches may offer insights into enhancing educational design.

An important aspect of introducing new educational technology systems is assessing the feasibility of end users adopting and using them. Curran et al. (2026) used the Technology Acceptance Model (TAM) (Davis, 1989) to explore factors affecting the adoption and usage of XR technologies in rural medical education. TAM suggests that technology adoption mainly depends on two key factors: perceived usefulness (PU) and perceived ease of use (PEOU). PU is the degree to which users believe technology will be useful for staying current in their skills. In this study, rural healthcare providers saw XR as helpful for increasing access to training, supporting preparation for HALO events, creating immersive and experiential learning opportunities, and enabling repeatable, self-directed education. PEOU refers to how easy it is to learn and use technology. Factors that affected ease of use included technical reliability, availability of IT support, usability, hardware setup, and user familiarity with XR systems. Participants also identified barriers, such as technical complexity, limited infrastructure, and steep learning curves that could hinder adoption. Figure 1 presents a conceptual framework based on the TAM to support the adoption and sustained use of XR in rural healthcare education. The left panel illustrates core TAM constructs, showing that PU and PEOU influence clinicians' attitudes toward XR, which in turn drives adoption. The middle panel outlines strategies to enhance PU and PEOU. PU is strengthened by aligning XR activities with rural clinical needs, using local cases, and supporting CPD for HALO events. PEOU is promoted by minimizing setup burden, integrating XR into existing workflows, and enabling flexible, accessible learning. The right panel highlights factors that cultivate positive attitudes and sustained use, including peer-endorsed learning, success stories, local champions, and continuous feedback. Together, these elements create a cycle that supports adoption, reinforces positive attitudes, and promotes long-term integration of XR in rural clinical education.

Figure 1. Adoption of Extended Reality (XR) in Rural Medical Education: A Technology Acceptance Model (TAM) Approach (Curran et al., 2026).



Overall, this programmatic research synthesis demonstrates that XR technologies offer promising opportunities to enhance SBME, improve access to training, and support experiential learning in rural healthcare settings. While implementation challenges remain, XR technologies represent an emerging and valuable approach to supporting healthcare education and CPD.

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