Could extended reality haptics be used in health-care education? A survey of health-care students, educators and clinicians

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Could extended reality haptics be used in healthcare education? A survey of healthcare students, educators, and clinicians.

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Abstract

Purpose: This cross-sectional survey investigated healthcare academics, clinicians and students perspectives of 1) healthcare simulation-based learning (SBL) and 2) eXtended Reality (XR) haptics use within healthcare education. Participants views regarding the application, barriers, and facilitators of SBL and XR haptics were explored

Design/ methodology/ approach: Online international cross-sectional survey of 178 participants.

Findings: The survey found high healthcare SBL use (n=97, 55.1%) but low awareness (n=48, 27.3%) or prior use of XR haptics (n=14, 7.9%). Participants expressed interest in XR haptic technology emphasising its potential in SBL, particularly for understanding of anatomy and physiology, enhancing clinical reasoning, and consultation and practical skills.

Research limitations/implications: Whilst there was interest in XR haptics, few participants described previous experience of using this technology in SBL. A large percentage of the participants were UK based. Most participants were from a nurse or physiotherapy professional background.

Practical implications: XR haptics is a developing technology for SBL in healthcare education. Whilst there was clear interest from survey participants, further research is now required to develop and evaluate the feasibility of using this technology in healthcare education.

Originality: Healthcare students, educators, and clinicians views on XR haptics have not previously been explored in the development and application of this technology. The findings of this survey will inform the development of XR learning scenarios that will be evaluated for feasibility in healthcare SBL.

Key words: Healthcare education, haptics, simulation, extended reality, skills, learning, touch.

Paper type: Research paper

Introduction

Healthcare teaching methods are increasingly incorporating advanced technologies to facilitate comprehensive understanding (Aiello, Cochrane, and Sevigny 2023), moving away from historical reliance on passive didactic approaches (Sahu et al. 2019). Experts advocate for a shift towards active learning (Børte, Nesje, and Lillejord 2023), prioritising active participation to promote meaningful learning experiences (Jolliffe 2015). Hands-on experience engages students by involving direct participation, thus fostering deeper understanding and skill acquisition through hands-on application (Rossoni et al. 2024). However, the solution to this problem is not clear as the value and methods of touch and its integration into advanced technologies to enhance healthcare education is uncertain.

Touch plays a pivotal role in human development and cognitive processes (Minogue and Jones 2006), particularly in hands-on skills (Pepito, Babate, and Dator 2023). In healthcare, it serves various purposes such as communication, diagnosis, and therapy (Roger et al. 2002). However, the transition from layperson touch to professional touch in healthcare is often overlooked, posing challenges for students (Wearn et al. 2020). Despite its importance, touch remains contentious, particularly due to concerns about sexual harassment (Boissonnault et al. 2017) and the limitations on touch-based learning imposed by events like the #MeToo movement and the COVID-19 pandemic (Davin et al. 2019, UK Government 2020).

In healthcare education, live models and clinical placements offer valuable exposure to develop professional touch, but real-life experiences may not always suffice due to patient guardedness and ethical concerns (Boissonnault et al. 2017, Chernikova et al. 2020, Jagsi and Lehmann Lisa 2004). Ensuring a safe learning environment is crucial to mitigate the overwhelming nature of clinical settings and maintain student performance (Pearce, Topping, and Willis 2022). Learning professional touch often involves observation, practice, and teaching, but traditional methods, such as the "see one, do one, teach one" may lack supervision and structured feedback, raising concerns about standards and competencies (Lenchus 2009, Rodriguez-Paz et al. 2009).

Healthcare education has utilised Simulation-based Learning (SBL) methods, like mannequins, peer simulation, and eXtended Reality (XR) to overcome traditional training limitations (Dalwood et al. 2020). SBL offers benefits including improved psychological safety, teamwork, decision-making, and clinical skills (Al-Ghareeb and Cooper 2016). The Nursing and Midwifery Council has increased simulation hours for students, recognising its educational value (Nursing and Midwifery Council 2024). However, existing XR healthcare education platforms, which provide limited sensory feedback (Kudry and Cohen 2022), may hinder the exposure to and development of gross motor skills needed for hands-on clinical interactions (Seibert and Shafer 2018).

XR is a term used interchangeably for virtual, augmented, and mixed reality. Haptics refers to technologies intended to provide touch feedback to users (Vezzoli et al. 2022). Haptics may enhance immersion and usability, facilitating more accurate touch-based interactions in simulated clinical scenarios. However, XR haptics research has to date been primarily focussed on touch during surgical procedures rather than on clinical skills that require direct touch (e.g. palpation) (Motaharifar et al. 2021). XR, especially with haptic gloves, is seen as a potential SBL method, offering a safer environment for developing clinical motor skills before real-world application. Haptic gloves provide kinaesthetic sense and tactile feedback, with potential application for clinical skills requiring direct touch (see Image 1). The use of XR haptic gloves may help support students in the development of professional touch. However, this topic has not yet been explored. Understanding clinical and educational needs, as well as end-user engagement, is crucial for effective development and deployment of XR haptics in healthcare (Brugha and Varvasovszky 2000).

Image 1 –Example of an XR haptic glove

Image created by authors

Aim and Objectives

This research aimed to explore healthcare academics, clinicians, and students knowledge of SBL, XR haptics, and their views on potential applications, barriers, and enablers to its use within healthcare education. Understanding these stakeholders' perspectives will inform the development of clinical scenarios that will evaluate the feasibility of XR haptic in healthcare education.

The objectives were to;

- Explore participants' prior experiences of healthcare SBL.
- Explore participants' knowledge and familiarity with XR haptic technology.
- Identify potential barriers to the implementation of XR haptic gloves in healthcare SBL.
- Explore potential enablers that could facilitate the successful implementation of XR haptic gloves in healthcare SBL.
- Gather participants' ideas and insights on clinical simulated scenarios where XR haptic gloves could be used in healthcare SBL.

Method

Design

An online survey was conducted from January 30th to April 1st, 2023. The survey, based on a Joint Information Systems Committee (JISC) questionnaire, was informed by literature and NHS policy on healthcare simulation (Health Education England 2018, 2020, 2021). Previous research on barriers and enablers to using high-fidelity patient simulation mannequins in nursing (Al-Ghareeb and Cooper 2016) served as a framework to explore stakeholders' perspectives on XR haptics in healthcare education, as no prior studies were found on this topic.

The survey gathered demographic data, followed by exploring participants past experiences with SBL. This step aimed to establish a baseline regarding the perceived value of SBL in healthcare education. Participants were categorised by their primary role to assess any role-specific differences in experiences. Subsequently, they were presented with identical questions regarding their previous encounters with XR haptics, including barriers and facilitators to its use, potential clinical applications, and rationales for its integration into healthcare education (see Figure 1).

Participants

Individuals eligible to participate included healthcare clinicians, educators, or students from any healthcare specialty or field, who were 18 years of age or older. Participants provided their primary job role within the questionnaire. The survey link was accessible worldwide, promoted via the authorship's personal social media and Coventry University's research and simulation team's social media accounts (LinkedIn and X). The survey was also distributed to all members of the Association of Advanced Practice Educators (AAPE) In the United Kingdom (UK).

Ethics and consent

The survey received ethical approval from Coventry University's ethics committee. Participants provided informed consent within the survey, understanding the research's nature, purpose, and anticipated impacts. Participation was voluntary, with all data anonymised and no personal identifiable details collected. Anonymised data was securely stored electronically on the lead researcher's password protected JISC online database account at Coventry University.

Survey development and completion

The survey underwent two pilot tests prior to its full release. Initially, it was piloted with 20 voluntary participants, including five healthcare students, nine clinicians, and six educators. After feedback, revisions were made which focussed on the structure of the survey and suggestions for clinical scenarios. A final pilot test was conducted with the authorship team to ensure usability. No further content changes were made after this.

The survey consisted of 56 questions, including Likert-style and multiple-choice questions, as well as opportunities for participants to provide free-text qualitative feedback.

Figure 1 – An outline of the survey design and question routing

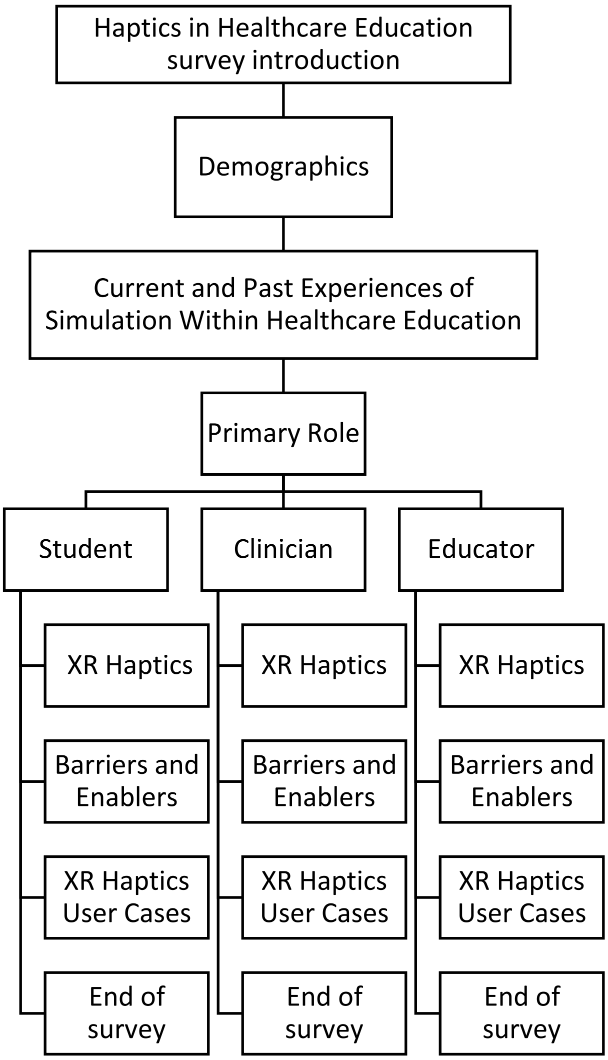

Figure created by authors

Prior to survey completion, all participants viewed a video demonstrating haptic glove technology in virtual reality. In the survey, participants were then asked a series of questions to explore their experiences and perceptions of XR haptics simulation, as well as potential barriers and enablers. Participants were presented with 22 clinical scenarios which were selected from the authorship experience and pilot feedback, and asked to rate their top five, with the option for additional qualitative feedback. Finally, participants were asked to provide reasons for their views on the usefulness of XR haptics. The survey allowed participants to opt out of any questions they felt they could not contribute to. The survey took approximately 10 minutes to complete.

The Consensus-based Checklist for Reporting of Survey Studies (CROSS) was chosen as a tool to guide the design and reporting of the survey findings. CROSS incorporates evidence-informed and expert consensus-based items to enhance the quality of survey studies, aiding researchers in ensuring reliability, reproducibility, and transparency in their surveys (Sharma et al. 2021).

Data analysis

Descriptive statistics including percentages, frequencies, medians, and interquartile ranges (IQR) (where data was not normally distributed) were used to summarise data, offering insight and group comparison. For comparing two or more groups, the Kruskal-Wallis test was used. This allowed assessment of differences between group medians without relying on strict distributional assumptions. IBM Statistical Package for the Social Sciences (SPSS) 26 facilitated statistical analysis (IBM Corporation 2019).

In the following sections the survey data is provided. In the data tables we provide the median and IQR scores for each question. In the text we refer to the percentage of participants agreeing or disagreeing with the statement. Agreement was defined in terms of the percentage of participants responding with a 1 (strongly agree) or 2 (agree). The percentage disagreeing involved combining responses 4 (disagree) and 5 (strongly disagree).

To interpret free-text data, content analysis was performed to identify themes and patterns, this was completed by two of the authors (MG and KMS). A collaborative approach within the authorship team ensured transparency and rigour through group discussions and consensus on findings (Kyngäs, Mikkonen, and Kääriäinen 2020). In line with the CROSS checklist (Sharma et al. 2021), the data and missing data is show in tables II to V.

Results

A total of 176 participants completed the survey. 43 participants (24.4%) identified as male, while 133 participants (75.6%) identified as female. Most participants (n=164, 93.2%) resided in the UK. Participants professional backgrounds were predominantly in nursing (n=69, 39.2%) or physiotherapy (n=69, 39.2%) (Table I). Ages ranged from 22-69, with a mean age of 40 years (male 41.93, SD 9.79; female 39.97, SD 11.07).

Categorising the participants based on their primary roles, 43 (24.4%) were students, 99 (56.3%) were clinicians, and 34 (19.3%) were educators.

Table I - Demographics of participants

	N=	Percentage of participants
Gender		
Male	43	24.4%
Female	133	75.6%
Primary Role		
Healthcare Student	43	24.4%
Healthcare Clinician	99	56.3%
Healthcare Educator	34	19.3%
Previously used simulation in healthcare education		
Yes	97	55.1%
No	75	42.6%
Unsure	4	2.3%
Previously used XR haptics in healthcare education		

Yes	14	8%
No	156	88.6%
Unsure	6	3.4%
Professional Background		
Biomedical scientist	1	0.6%
Chiropodist / podiatrist	10	5.7%
Chiropractic	1	0.6%
Dietician	1	0.6%
Educational Developer	1	0.6%
Health advocate	1	0.6%
Medic / Doctor / Surgeon / Physician	1	0.6%
Midwife	2	1.1%
Nurse	69	39.2%
Occupational therapist	3	1.7%
Operating Department Practitioner	3	1.7%
Paramedic / Emergency Medical Technician / Ambulance Technician	10	5.7%
Pharmacist	2	1.2%
Physician associate	1	0.6%
Physiotherapist / Physical Therapist	69	39.2%
Radiographer	1	0.6%

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Experiences of simulation within healthcare education

Of the 176 participants, 97 (55.1%) had prior experience with using simulation in their education. 151 participants (87.3%) highlighted the importance of teacher involvement during simulation sessions. 166 participants (96%) recognised SBL as a method to safely expose users to challenging clinical scenarios, enhancing active participation in education (n=157, 89.2%). While 64 participants (36.8%) agreed that traditional teaching methods were inadequate, 63 (36.2%) were neutral, and 47 (27%) disagreed. Most participants (n= 165, 93.8%) found simulation to be a fun learning approach, expressing a desire for its increased incorporation into healthcare education.

Statistical significance was found between professional groups, with educators believing simulation could safely expose students to challenging clinical scenarios (p=0.032) compared to students. Previous simulation users reported that simulation could safely expose individuals to challenging scenarios (p=0.014) compared to non-users, possibly due to reported resource shortages (p=0.007) and fewer opportunities (p=0.015) for non-users compared to prior users. No other statistical differences were found between the three professional groups (p>0.05).

Table II – Simulation in healthcare education and the role of touch

	Healthcare Students (n=43)	Healthcare Clinicians (n=99)	Healthcare Educators (n=34)

	N=	Median (IQR)	N=	Median (IQR)	N=	Median (IQR)
Teacher involvement within simulation is needed to aid education	42	2 (1)	97	2 (1)	34	2 (2)
Simulation can safely expose you to challenging scenarios	42	2 (1)	97	1 (1)	34	1 (1)
I learn more from "actively doing" rather than "classroom listening"	43	1 (1)	99	1 (1)	34	2 (1)
Current teaching methods are inadequate to support learning	43	3 (1)	97	3 (2)	34	3 (2)
I feel simulation is a fun way to learn	43	2 (1)	99	2 (1)	34	2 (1)
I would like to use simulation more in my healthcare education	43	1 (1)	99	2 (1)	34	1 (1)
I believe touch forms an important part of healthcare education	42	1 (1)	99	1 (1)	34	1 (1)
I feel touch within healthcare education is actively encouraged	43	2 (2)	98	2 (2)	34	2 (2)
I feel touch within simulation is important	43	2 (1)	99	2 (1)	34	1 (1)
Realistic touch during simulation improves interaction	43	2 (1)	99	2 (1)	34	1 (1)
Realistic touch during simulation improves healthcare education	43	2 (1)	98	2 (1)	33	1 (1)
I feel safe to touch others during routine hands-on practice	43	2 (0)	99	2 (1)	34	2 (2)
I feel comfortable to touch others during routine hands-on practice	43	2 (2)	99	2 (1)	34	2 (1)
I feel safe when others touch me during routine hands-on practice	42	2 (2)	98	2 (1)	34	2 (1)
I feel comfortable when others touch me during routine hands-on practice	42	2 (2)	98	2 (1)	34	2 (1)

Table created by authors

Knowledge and use of XR haptics

Of the 176 participants, 118 participants (67.0%) were unaware of XR haptic technology, with 156 (86.6%) lacking prior experience in healthcare simulation using XR haptic devices. Most participants (n=151, 88.3%) emphasised the importance of teacher involvement in XR haptics simulation for education. Additionally, 160 participants (92.5%) believed that XR haptics simulation could offer safe exposure to challenging scenarios and perceived it as an enjoyable learning method (n= 168, 95.5%).

The interest in integrating XR haptics simulation into future healthcare education was high, with 156 participants (89.7%) expressing agreement. Furthermore, participants recognised the significance of touch feedback within XR simulation (n=158, 89.8%), acknowledging its potential to enhance interaction (n= 165, 94.3%), and application to healthcare education (n= 165, 94.8%). In terms of safety and comfort, 95 participants (55.2%) agreed they would feel safer touching others in XR haptics simulation compared to routine hands-on practice, with 88 (51.2%) participants indicating higher psychological comfort levels. Moreover, 79 (45.9%) participants agreed that knowing XR haptics simulation could replace the need for them to be touched by others during routine practice would enhance their sense of safety, while 84 (48.6%) expressed increased comfort in such a scenario.

The role of touch in healthcare education

Touch was deemed an integral component of healthcare education by 166 participants (94.3%), with 109 participants (62.3%) perceiving that touch was actively encouraged in this context. During the use of simulations, 159 participants (90.3%) emphasised the importance of realistic touch, enhancing interaction (n=160, 92.5%) and improving healthcare education (n=153, 88%). Regarding routine hands-on practice, 146 participants (83%) felt safe and comfortable touching others, as well as feeling safe (n=135, 77.6%) and comfortable (n=134, 77%) when being touched.

Students expressed feeling safer (p=0.004) and more comfortable (p=0.005) to touch others in XR haptics simulation compared to routine hands-on practices. Students reported that they would also feel safer (p=0.016) and more comfortable (p=0.010) knowing XR haptics simulation could replace the need to be touched by others. Female participants echoed these sentiments, feeling less safe (p=0.025) and less comfortable (p=0.013) with traditional hands-on touch compared to male participants. Table III summarises responses regarding views on XR haptics.

Table III – Knowledge, use and perceptions of XR haptics

	Healthcare Students (n=43)		Healthcare Clinicians (n=99)		Healthcare Educators (n=34)	
	N=	Median (IQR)	N=	Median (IQR)	N=	Median (IQR)
Teacher involvement within XR haptics simulation would be important to aid education	43	2 (1)	98	2 (1)	30	2 (1)
XR haptics simulation could safely expose me to challenging scenarios	43	2 (1)	97	2 (1)	33	2 (1)
I feel XR haptics simulation would be a fun way to learn	43	1 (1)	99	2 (1)	34	1 (1)
I would like to use XR haptics simulation in my future healthcare education	43	1 (1)	98	2 (1)	34	1 (1)
I feel touch feedback within XR simulation would be important	43	2 (1)	99	2 (1)	33	1 (1)
Realistic touch during XR haptics simulation could improve interaction	43	1 (1)	99	2 (1)	33	1 (1)
Realistic touch during XR haptics simulation could improve healthcare education	43	1 (1)	98	2 (1)	33	1 (1)
I would feel safer to touch others in XR haptics simulation compared to routine hands-on practice	43	2 (1)	96	3 (1)	33	3 (1)
I would feel more comfortable to touch others in XR haptics simulation compared to routine hands-on practice	42	2 (1)	97	3 (1)	33	3 (1)

I would feel safer knowing XR haptics simulation could replace the need for me to be touched by others during routine hands-on practice	41	2 (2)	98	3 (1)	33	3 (2)
I would feel more comfortable knowing XR haptics simulation could replace the need for me to be touched by others during routine hands-on practice	42	2 (2)	98	3 (1)	33	3 (2)

Table created by authors

Barriers and enablers

The analysis showed significant agreement among participants regarding various challenges in implementing XR haptics simulation-based education (Table IV). 129 (73.3%) participants cited time constraints, 109 (61.9%) expressed fear of technology, 153 (87.4%) recognised a shortage of educators, 160 (92.5%) agreed on the lack of appropriate simulation resources, 149 (85.1%) identified a lack of opportunity to engage with simulation resources, 126 (75%) acknowledged the lack of resource maintenance, and 125 (73.5%) agreed on the absence of technical support for developing simulation scenarios. 102 (61.8%) participants disagreed with the notion that XR haptics simulation education was not applicable to their curriculum.

Analysis of free text feedback revealed various barrier themes, encompassing "financial factors," "resistance to change," "educational relevance and utility," "practicality and logistics," and "efficacy and advantages." Specific feedback on " *Price and realistic touch and fine motor touch*" along with accessibility *"numbers of learners is an issue when using this type of technology and thus allowing equity of experience*" highlight some of the key challenges in the use and adoption of this technology.

Table IV - Barriers to the implementation of XR haptics in healthcare education

	Healthcare Students (n=43)		Healthcare Clinicians (n=99)		Healthcare Educators (n=34)	
	N=	Median (IQR)	N=	Median (IQR)	N=	Median (IQR)
Lack of time	43	2 (1)	98	2 (2)	34	2 (2)
Fear of technology	43	2 (1)	99	2 (1)	34	2 (2)
Lack of educators to deliver simulation sessions effectively	42	2 (1)	99	2 (1)	34	2 (1)
Lack of appropriate simulation resources	42	2 (1)	97	2 (1)	34	2 (1)
Lack of opportunity to engage with simulation resources	43	2 (1)	98	2 (1)	34	2 (1)
Lack of maintenance of simulation resources	42	2 (1)	95	2 (1)	31	2 (1)
XR haptics simulation education is not applicable to my curriculum	39	3 (2)	96	4 (2)	32	4 (2)

Lack of technical support to develop simulation scenarios	43	2 (2)	93	2 (2)	34	2 (1)

Table created by authors

In terms of enabling the use of XR haptics, the findings (Table V) demonstrated a strong consensus among participants regarding the advancement of XR haptics in healthcare education. 165 (96.5%) participants emphasised the importance of training opportunities for users, while 147 (86%) acknowledged the significance of administrative support in accessing simulation resources. 166 (94.9%) participants recognised the critical role of skilled educators to support its use, and 165 (94.3%) agreed on the influence of integrating simulation into teaching strategies. Additionally, 130 (75.6%) respondents perceived educational institutions as superior places to study if they utilised XR haptic gloves. The need for a dedicated simulation coordinator was supported by 164 (94.3%) participants, with 164 (93.7%) stressing the importance of technical support. Lastly, 167 (95.4%) participants recognised the value of educational support in delivering XR haptics simulation sessions.

The content analysis of free text feedback, indicated potential enablers to integrating XR haptics in healthcare education to include: "Adequate Time and Funding," highlighting the role of financial resources in implementation, "Technological Advancement," emphasising continual progress in XR haptic technology, and "Curriculum Integration." Participants stressed that XR haptics should evolve alongside technology and be "*mandatory for clinical scenarios.”* Additionally, there was a consensus on the necessity for SBL to support natural interaction with "*full hand extension and flexion*.”

Table V - Enablers to implementing XR haptics in healthcare education

	Healthcare Students (n=43)		Healthcare Clinicians (n=99)		Healthcare Educators (n=34)	
	N=	Median (IQR)	N=	Median (IQR)	N=	Median (IQR)
Training opportunities for users	43	2 (1)	98	2 (1)	34	1 (1)
Administrative support to access simulation	42	2 (1)	95	2 (1)	34	2 (1)
Skilled and engaging educators	43	1 (1)	98	2 (1)	34	2 (1)
Embedded within overall teaching strategies	43	2 (1)	97	2 (1)	34	2 (1)
Education institution seen as a superior place to study	43	2 (1)	96	2 (2)	33	2 (2)
A dedicated simulation coordinator	42	2 (1)	97	2 (1)	34	2 (1)
Technical support to develop simulation scenarios	43	2 (1)	98	2 (1)	34	1 (1)
Educational support to deliver simulation sessions	43	1 (1)	98	2 (1)	34	1 (1)

Table created by authors

Simulation scenarios

Supporting anatomical and physiological education ranked first among healthcare clinicians (n=79, 79.8%) and second among healthcare students (n=30, 69.8%). Supporting clinical decision making ranked first for healthcare students (n=31, 72.1%), second for healthcare clinicians (n=53, 53.5%), and third for educators (n=19, 55.9%). Practice-specific skills ranked first for healthcare educators (n=22, 64.7%) but fifth for clinicians (n=33, 33.3%). Students highly rated specific practical skills such as moving a joint (n=17, 39.5%) and palpating sensitive areas (n=12, 27.9%). Lastly, developing consultation skills ranked highly across all three groups, particularly among students (n=22, 51.2%) and clinicians (n=39, 39.4%).

Content analysis of unstructured free text data revealed various additional use cases for XR haptics. Themes included "Clinical assessment and examination," where participants noted their potential to enhance realism and effectiveness in medical simulations. "Invasive procedures" highlighted their utility in simulating surgeries and sensitive region examinations. "Rehabilitation" emerged as a significant application for motor skills recovery. In "Obstetrics and gynaecology," participants saw potential for enhanced training, including simulating gestation stages. Lastly, "Safety" emphasised their use in high-risk scenarios and human factor-based simulations. The responses are summarised per participant group in Table VI below.

Table VI -Top 5 scenario use cases chosen between groups

Rank	Healthcare students	Healthcare clinicians	Healthcare educators
1.	Supporting clinical decision making (n=31, 72.1%)	Supporting anatomical and physiological education (n=79, 79.8%)	Practice specific skills (n=22, 64.7%)
2.	Supporting anatomical and physiological education (n=30, 69.8%)	Supporting clinical decision making (n=53, 53.5%)	Supporting anatomical and physiological education (n=21, 61.8%)
3.	Developing consultation skills (n=22, 51.2%)	Developing consultation skills (n=39, 39.4%)	Supporting clinical decision making (n=19, 55.9%)
4.	Moving a joint (n=17, 39.5%)	Administering injections (n=35, 35.4%)	Developing consultation skills (n=9, 26.5%)
5.	Palpate sensitive areas (n=12 27.9%)	Practice specific skills (n=33, 33.3%)	Practice orthopaedic tests (n=9, 26.5%)

Table created by authors

Reasons for using XR haptics in healthcare education

Among clinicians, the primary reason for using XR haptics in healthcare education was practicing in general (n=85, 85.9%), while among healthcare students, it ranked second (n=32, 74.4%) (Table VII). Healthcare students ranked learning in a fun way as the top reason (n=34, 79.1%), whereas clinicians ranked it second (n=73, 73.7%). For healthcare educators, the ability to safely learn from mistakes was the top-ranked reason (n=28, 82.4%).

In the free text data participants highlighted the gloves' capacity to enhance learning and skill development by offering practice opportunities, potentially fostering muscle, and procedural memory. Additionally, they emphasised patient-centric applications, highlighting safety and exposure to diverse pathologies. Convenience and self-paced learning were also noted, with participants valuing readily accessible scenarios. Lastly, they anticipated that haptic glove XR interaction would enhance understanding and feedback, contributing to a deeper comprehension of the subject matter and more comprehensive feedback in the educational context.

Table VII - Top 5 reasons to use XR haptics in healthcare education between groups

Healthcare students	**Healthcare clinicians**	**Healthcare educators**
Fun way to learn (n=34, 79.1%)	Ability to practice (n=85, 85.9%)	Safely learn from mistakes (n=28, 82.4%)
Ability to practice (n=32, 74.4%)	Fun way to learn (n=73, 73.7%)	Ability to practice (n=27, 79.4%)
Interactive (n=28, 65.1%)	Interactive (n=70, 70.7%)	Fun way to learn (n=27, 79.4%)
Physically a safer environment to learn in (n=27, 62.8%)	Safely learn from mistakes (n=70, 70.7%)	Range of potential immersive environments (n=24, 70.6%)
Reflective experience (n=26, 60.5%)	Physically a safer environment to learn in (n=62 62.6%)	Interactive (n=23, 67.6%)

Table created by authors

Discussion

This survey aimed to explore healthcare academics, clinicians, and students knowledge of healthcare simulation, XR haptics, and their views on potential applications, barriers, and enablers to its use within healthcare education.

The survey findings suggest a strong demand for integrating XR haptic technology into clinical scenarios for healthcare education, revealing its potential to significantly enhance skill development and improve patient care outcomes. Participants expressed a desire for immersive experiences that refine clinical reasoning, practical skills, anatomy and physiology knowledge, and communication in patient care.

Development and implementation of simulation-based healthcare education

This survey highlights varying experiences but a willingness to engage with simulation in healthcare education. The participants were drawn across a number of healthcare professions, but particularly from nursing and physiotherapy. The potential benefits of simulation in these specialities are well recognised and the findings reinforce the perceived value of simulation in advancing motor skills (Cook 2014).

Our survey findings on barriers to XR haptics in SBL mirror those of previous research on high-fidelity simulation manikin use in nursing education (Al-Ghareeb and Cooper 2016), including factors like lack of time, fear of technology, and financial constraints. The results of the survey suggest that an obstacle to the integration of haptic technology into healthcare education is its considerable financial expense.

The participants drew attention to the need for teacher involvement and strategic integration of simulations into educational scenarios. Simulations are not just standalone activities but should be strategically integrated into a comprehensive educational framework (Chernikova et al. 2020). The recent shift to virtual environments during the Covid-19 pandemic lacked application of pedagogical principles (Lewandowski, Landry, and Prieto 2021), which may have limited the value of SBL. Educators play a crucial role in simulation-based learning, but their lack of knowledge about XR haptics poses a potential barrier to its adoption. Without awareness of technology's potential and limitations, scenarios become technologically driven rather than learner-centred (Logeswaran et al. 2021).

Immersive technology in education has gained traction, evidenced by initiatives like the NHS National Simulation-Based Framework (Health Education England 2018). Amongst the feedback from our study, an interesting comment was made that there is now a societal expectation for the inclusion of enhanced technology within healthcare education curricula, suggesting it should be an intrinsic part of the curriculum. This approach ensures that learners have structured and consistent exposure to the technology throughout their education (Chernikova et al. 2020). This is all founded on the paramount need for a skilled educator to combine the application and utility of such a technology in healthcare (Chernikova et al. 2020, Health Education England 2020).

This knowledge helps other studies by highlighting the willingness to engage with simulation across healthcare professions, particularly nursing and physiotherapy, and the benefits and barriers to XR haptics integration. It emphasises the need for strategic, teacher-led integration and structured curricula to maximise the technology's potential in healthcare education.

Experience of, and expected value of XR haptics

Despite limited prior awareness and use of XR haptics by participants, there was a clear interest in integrating XR haptic technology into healthcare simulation education. Feedback suggests strong interest and recognition of the potential value. However, we must be aware that marketing videos may provide an overly positive representation of the technologies capabilities and therefore we should remain cautious when interpreting the results.

Respondents highlighted XR haptic glove simulations may provide value for experiencing healthcare procedures virtually, enhancing understanding and proficiency in a low-risk setting. This aligns with previous research indicating that haptic feedback improves XR simulation training effects (Rangarajan, Davis, and Pucher 2020). The potential adoption of XR haptic gloves in healthcare education is supported by compelling arguments from participants, such as the emphasis on practice, clinicians and students recognising the value of repeated virtual practice for enhancing real-life patient care competence, confidence, and outcomes. Enhanced understanding and feedback within a virtual environment foster critical thinking and analytical skills, nurturing future healthcare leaders (Handke et al. 2022).

Viewing XR haptic gloves as a fun learning tool aligns with pedagogical principles, combating learner fatigue and fostering positive attitudes towards ongoing education. Engaged learners are more likely to retain information and develop a deeper understanding of complex concepts, as Confucius (450 BC) once said "*Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand*" (Halm 2015). Safety and learning from mistakes are central ethical concerns addressed by XR haptics, providing a low-risk space for experimentation. Nevertheless, it is imperative to enhance our theoretical comprehension of the sensory mechanisms that drive learning simultaneously with the development and execution of technology.

Introducing innovative technology or changing conventional learning paradigms requires addressing cultural resistance. The diffusion of innovation framework underscores the importance of effectively structuring change for acceptance (Rogers, Singhal, and Quinlan 2019). In order to explore this technology, educators must prioritise their own education in haptics, ensuring that their utilisation of it is grounded in solid pedagogical theory and informed by user feedback to optimise its utilisation and integrations.

The preference shown by students and female participants towards XR haptic simulation instead of traditional hands-on physical touch suggests a need to pause and reconsider our approach in how we navigate touch in healthcare education. This may relate closely to the larger societal patterns concerning perceptions of physical contact (Boissonnault et al. 2017, Davin et al. 2019, Norris and Wainwright 2022). The results of this study raise doubts about the potential adverse effects of traditional hands-on training on both physical and psychological safety. However, it also offers an alternative method in hands-on healthcare education, urging further exploration into its implications for the development of clinical education and associated patient care.

Whilst there was a general sense of agreement across participant groups, there is room for further analysis to explore the differences between professional groups and levels of experience. A balanced approach is needed to inform curriculum development that combines expert guidance, innovative pedagogy, and technological advancements in healthcare education. The survey indicates broad support for XR haptics, but XR methods may not always surpass traditional ones (Makransky et al. 2021), highlighting the need for high-quality research. Despite limited validation, XR haptic technology has gained traction due to improved affordability and accessibility. Participants noted this progress as an enabler, with commercialisation making devices more appealing. However, the high financial cost and return on investment need further exploration.

How is XR haptics best applied?

The survey examined which healthcare scenarios are best suited for XR haptics, despite its limitations in providing "real touch." XR haptics has significant potential for natural interaction, safer training environments, and low-risk practice for future healthcare professionals. Therefore, XR haptics should be developed and implemented with use cases and learner needs in mind (Logeswaran et al. 2021).

Participants identified scenarios where XR haptics could be useful, such as practicing joint movement, palpation, anatomical and physiological education, clinical decision-making, and consultation skills. XR haptic gloves, despite limited tactile feedback (Lavoie, Hebert, and Chapman 2024), offer a natural approach to XR interactions essential for these manual healthcare tasks. Grounded XR haptic feedback has shown promise in improving motor learning in palpation tasks (Baillie et al. 2010). Further qualitative research will help understand the intrinsic motivations and mechanisms behind users' integration of XR haptics in healthcare education, offering depth and insight that quantitative methods might overlook or undervalue.

Limitations

This research has explored the current understanding, experiences, and perceptions of a range of educators, clinicians and students related to SBL and XR haptics. The survey was exploratory and aims to guide future research in this area and the development of XR haptics.

As the survey was explorative, the sample size is constrained, and limited in the number of respondents with prior experience of using haptic technology, impacting the depth of insights obtained. With a more varied sample, and different professional group, individuals familiar with haptic gloves might offer nuanced perspectives crucial for integrating XR haptic gloves into healthcare education. Arguably though, it is also important to reach and understand the views of those less familiar with the technology, when looking to improve acceptance and adoption.

The demographic data suggests a reasonably narrow sample. For example, 75% of participants identified as female. The main difference in terms of gender was found to be in relation to the participants safety and comfort of being touched, with female participants reporting they would feel an increased level of safety and comfort knowing that XR haptic glove simulation could replace the need for them to be touched by others during routine hands-on practice. The female dominant sample reflects real-world healthcare demographics (NHS employers 2019) arguably enhances external validity, but it should be recognised that the sample may present some gender bias.

There was also an unequal distribution across professional roles, with more clinicians than students or educators, and most respondents identifying as nurses or physiotherapists relative to other professional groups. The clinicians may have a good understanding of the clinical skills requirements, and the needs of recent graduates when they reach employment, but alternatively may have some distance from the educational experience.

Conclusion

This study offers a novel insight into the potential of XR haptics in healthcare education, exploring uses and applications across various healthcare professions, but particularly to nursing and physiotherapy. The findings suggest XR haptic glove technology may enhance healthcare interactions, based on physical touch, by providing a safer environment for healthcare education, improved clinical decision making with respondents emphasising the potential for anatomical and physiological education. Identified barriers to adoption include lack of supportive evidence, shortage of skilled educators, and limited simulation resources. Conversely, the enablers are perceived to be increased safety, and the provision of good educational support, and technical assistance. The study initiates an evidence-informed analysis of XR haptics in healthcare education, to inform future technical development and further research to understand the potential for skill development and retention.

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