applied sciences

Article

The Use of Mixed Reality in Training Trainers—A Single-Centre Study

Prabhjot Singh Malhotra [1], Swati Jain [1,2,3,*], Silvia Stefanova Karcheva [1] and Adel Helmy [1,3]

1 Cambridge University Hospitals NHS Foundation Trust, Cambridge CB2 0QQ, UK; prabhjotsingh.malhotra@nhs.net (P.S.M.); silvia.karcheva1@nhs.net (S.S.K.); adel.helmy@nhs.net (A.H.)
2 Division of Neurosurgery, University Surgical Cluster, National University Health System, 1E Kent Ridge Road, Singapore 119074, Singapore
3 Department of Clinical Neurosciences, E.D. Adrian Building, Forvie Site, Robinson Way, Cambridge CB2 2PY, UK
* Correspondence: sj657@cam.ac.uk

Abstract: There has been an exponential increase in the utility of mixed-reality (MR) software as a tool for medical education and training due to its immersive and interactive capabilities. Whilst it has been progressively used in surgical training or in simulation training, there is a significant lack of using it to train the "trainers". In this single-centre prospective study, MR technology was used to deliver a dedicated 2-h tutorial in surgical training to two cohorts of postgraduate students attending a course on clinical research and education. The Microsoft HoloLens 2 was used to run mixed-reality software capable of rendering CT scan images of a normal brain, an MRI of a large meningioma, an abdominal–pelvic CT scan, and a 3D-printed cranioplasty scan. The participants were then asked to complete a post-usage questionnaire in an anonymous manner. Fourteen participants attended the teaching session and completed the post-usage questionnaire. Scores obtained on the User Experience Questionnaire (UEQ) revealed that MR technology is rated "Excellent" on quality aspects for Attractiveness, Stimulation and Novelty. This prospective study provides insight into incorporating MR in training the trainers, allowing them to be equipped with the technology to imparting education to the next generation across various disciplines.

Keywords: surgical training; mixed reality; postgraduate teaching; medical education; surgical simulation; anatomy demonstration

Academic Editor: Bruno Chrcanovic

Received: 3 February 2025
Revised: 17 February 2025
Accepted: 19 February 2025
Published: 24 February 2025

Citation: Malhotra, P.S.; Jain, S.; Karcheva, S.S.; Helmy, A. The Use of Mixed Reality in Training Trainers—A Single-Centre Study. *Appl. Sci.* **2025**, *15*, 2403. https://doi.org/10.3390/app15052403

1. Introduction

Recent times have seen an exponential increase in the utility of mixed-reality (MR) software as a tool for education and training. Due to its immersive and interactive capabilities, MR technology offers an immense potential for training surgical trainees, medical students and healthcare professionals [1–3]. MR technology allows users to simultaneously visualise a combined "real" and "virtual" environment in real time. Currently, MR software is supported on a variety of devices, including smartphones and head-mounted devices such as Google Glass, Microsoft HoloLens, Oculus Rift VR, and the Samsung Gear VR [4]. Several surgical specialties have adopted MR technology in medical training as it offers a three-dimensional (3D) visualisation of patient-specific anatomy acquired through CT and MRI images [5]. This provides trainees with an intuitive means of evaluating imaging data in a 3D manner in conjunction with surgical pathologies [6].

There is increasing evidence to demonstrate that MR technology allows residents, trainees and students to overcome the limitations of didactic video sessions by offering 3D visualisation of structures [7,8]. This in turn facilitates better comprehension of anatomy and enhances skill progression [9]. Furthermore, MR technology is a cost-effective modality that can be adopted with relatively low preparation requirements when compared to other more expensive hands-on simulation models [10].

However, these studies provide little information on whether future trainers can be trained to incorporate this MR platform in their education curriculums. To make MR-based training sustainable, it is important to ensure that there are systems set in place where future trainers are also provided regular training on new technologies and software using MR.

In this study, we evaluated two cohorts of participants who attained a postgraduate certificate in clinical research and education. The authors demonstrate the ease with which MR can be introduced in teaching the trainers. The study also showcases that wider exposure allows the generation of ideas for implementation in different resource settings.

2. Literature Review

Suresh et al. (2022) [11] reviewed 45 studies and assessed the validity rating of augmented reality (AR) in surgical training. In total, seven of these studies covered the use of a Microsoft HoloLens across the following specialties: urology, neurosurgery, gynaecology, general surgery and cardiothoracic surgery. HoloLens-assisted AR received a strong validity rating for surgical education and training, translating to a considerable reduction in error rates as well as an improvement in procedural times and economy of movement. Participants also reported increased self-perceived knowledge and confidence while enduring a relatively lesser cognitive load during task performance.

Similarly, a randomised control trial (RCT) for orthopaedic training demonstrated that the use of AR led to a faster learning curve to achieve the same overall level of competency [12]. These findings have been further corroborated by Sun et al. (2023) [13], where a review of 13 studies on the application of AR in simulation and training for hip surgery found it to be an extremely useful tool for pre-operative planning, reducing procedural times and surgical risk along with intraoperative radiation exposure.

Augmented and mixed reality have also seen a rapid uptake in neurosurgical and spine training. Bui et al. (2024) [14] reviewed eight studies, including three RCTs, that evaluated the performance of AR models for teaching procedures to neurosurgical trainees. These studies simulated procedures such as percutaneous spinal needle placement and percutaneous lumbar pedicle screw placement. Their results add to the evidence base that MR/AR technology enhances skill retention, preoperative planning and intraoperative execution, but that the main current limitation of such educational platforms is a lack of haptic feedback.

In 2011, Luciano et al. [15] evaluated the use of an AR 3D simulator with haptic feedback as a training tool for thoracic pedicle screw placement and observed a 15% mean score improvement in performance accuracy, denoting the benefit of AR for training junior residents and surgeons. Moreover, a review by Ghaednia et al. (2021) [16] on the applications of AR in spine anatomy education found that while the technology potentially increases learner immersion and engagement, notable drawbacks include headaches, dizziness, and blurred vision.

Not surprisingly, MR technology has increasingly been adopted across most surgical specialties. Li et al. (2023) [17] demonstrated higher test scores for residents in vascular surgery with MR-assisted teaching in comparison to traditional teaching methods. Similarly, a systematic review on the application of VR/AR in oral and maxillofacial surgery found 13 manuscripts on virtual education and training [18], while Mishra et al. (2022) [19] found 26 studies on virtual neurosurgery training. In 2022, a collaborative study between King's College London and Imperial College London involved the creation of a novel MR training curriculum for robot-assisted radical prostatectomy. Their results demonstrated that virtual surgical mentorship could be a feasible and cost-effective alternative to traditional training methods offering the potential to improve technical skills [20].

As discussed above, while MR's utility has been well demonstrated in teaching anatomy, surgical approaches, and interventions for patient care, whether its utility can be expanded across other aspects of education remains an unanswered question. Training the trainers (TOT) or residents as teachers (RATs) are often referred to as courses designed to inculcate the value of teaching amongst the junior trainees and doctors. The aim of these courses is to teach effective methods of teaching and communication to impart new knowledge. There is no available research or published articles that demonstrate the utility of incorporating MR in training the future trainers. The authors queried if the incorporation of MR in these courses is feasible to allow regular and seamless integration of MR in education.

3. Materials and Methods

A single-centre prospective study was conducted over a 2-year period at Cambridge University Hospitals. Two cohorts of students attending a course on postgraduate certificate on education and clinical research were approached for this study. As part of understanding new technologies in medicine, a dedicated 2-h period was utilised to introduce the use of mixed-reality technology in education. The students were not asked to prepare for this session and no study materials were provided prior to the teaching session.

For this study, a Microsoft HoloLens 2 was used. After a general introduction of the team's experience with mixed reality [8], a brief demonstration on the use of mixed-reality headsets was given for 15 min. The audience was divided into 3 groups due to the availability of 3 headsets. Two trainers with previous experience in utilising the MR headsets conducted the session.

One headset was connected to a livestream display of the usage. Computed tomography (CT) of a normal brain, magnetic resonance imaging (MRI) of a large meningioma, a CT of abdomen pelvis, and a 3D-printed cranioplasty scan were displayed using the headset. Anonymized preoperative computed tomography (CT)/magnetic resonance imaging (MRI) obtained from 3 patients admitted to the department was used. Consent was obtained from all patients to utilise their imaging without any identifiers for neurosurgical teaching. The imaging files were uploaded onto the Microsoft Azure Cloud. The images were anonymized prior to uploading and processing. For the purposes of this study, we used Virtual Surgery Intelligence (VSI, VSI HoloMedicine by apoQlar, Hamburg, Germany) Version 1.9 software. VSI provided the software capability for image rendering. It converted the CT and MRI files in Digital Imaging and Communications in Medicine (DICOM) standard into a 3D rendering. VSI did not require the modification of imaging protocols for the rendering of the images. Hence, this software was used for the purposes of the study to look at the feasibility of teaching. Interchanging between all 4 images was carried out to allow the participants to visualise and interact in the mixed-reality environment. The trainees were then asked to complete a post-usage questionnaire in an anonymous fashion. Due to the anonymous and voluntary nature of the survey, ethical approval was not needed.

Two questionnaires were provided to the trainees after the session. Trainees were allowed to provide anonymous responses. A formalised questionnaire was used to evaluate the possibility of using MR in neurosurgery training (Questionnaire SA). Each question was scaled from 1 to 7, with 1 referring to strongly disagree and 7 referring to strongly agree. This questionnaire was adapted from the study by Alfalah (2018) [21] that compared traditional teaching modalities with VR. To evaluate the trainee feedback in using a MR platform, the User Experience Questionnaire (UEQ) [22] was employed (Questionnaire

SB). UEQ 7 is a 26-item 7-point scale to understand the user experience in utilising a commercially available device. These values are then converted to negative or positive values, ranging from −3 up to +3. Values between −0.8 and 0.8 represent a neutral evaluation of the corresponding scale, values > 0.8 represent a positive evaluation, and values < 0.8 represent a negative evaluation. The authors have previously utilised the same user feedback in their previous study [8].

4. Results

A total of 14 participants attended the teaching session. All 14 participants answered the survey questionnaire at the end of the teaching session. Of these, 10 were Surgical/Foundation Trainee Doctors, whereas 4 belonged to allied health professional roles (2 clinical nurse specialists and 2 clinical nurse educators).

Didactic teaching was the most frequently selected modality amongst our participants in terms of their preference for anatomy teaching (Figure 1). Ten out of fourteen participants had never utilised an MR device in education prior to this session (Figure 2).

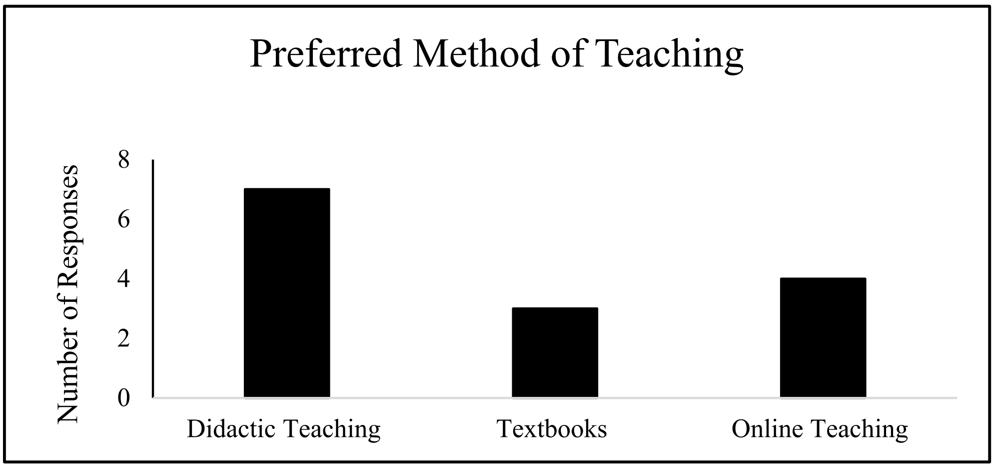

Figure 1. Bar chart distribution of preferred methods of teaching.

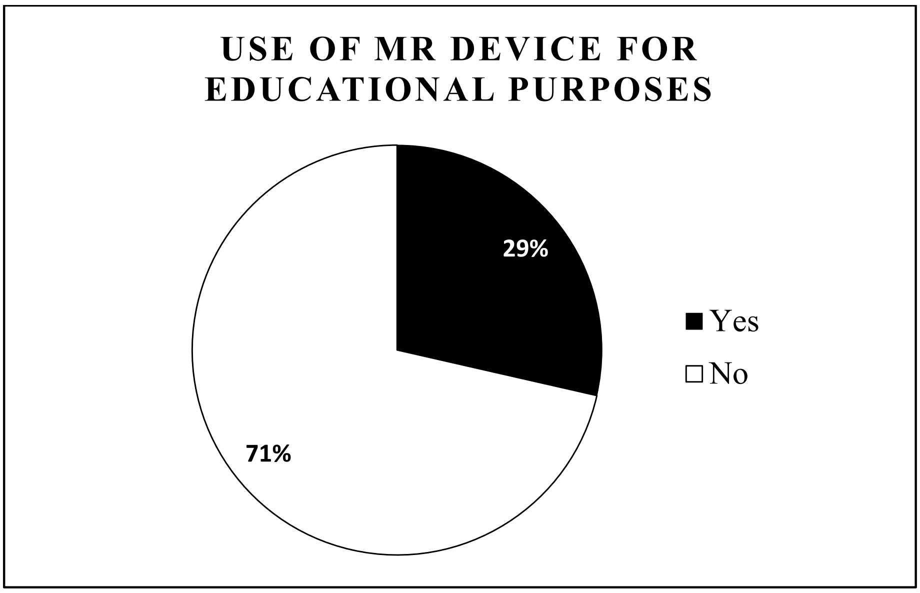

Figure 2. A pie chart representing the pre-existing experience of users interacting with MR-based devices.

The authors evaluated users' experience of the mixed-reality device using the UEQ. Only 29% of the subjects had previous experience of utilising a MR-based device in their professional career. Figure 3 reflects the range of mean responses generated by the UEQ Data Analysis Tool on a scale from −3 (horribly bad) to +3 (extremely good) across the 26-item User Experience Questionnaire. This was conducted in line with the authors' previous work on understanding resident experience in MR devices [8].

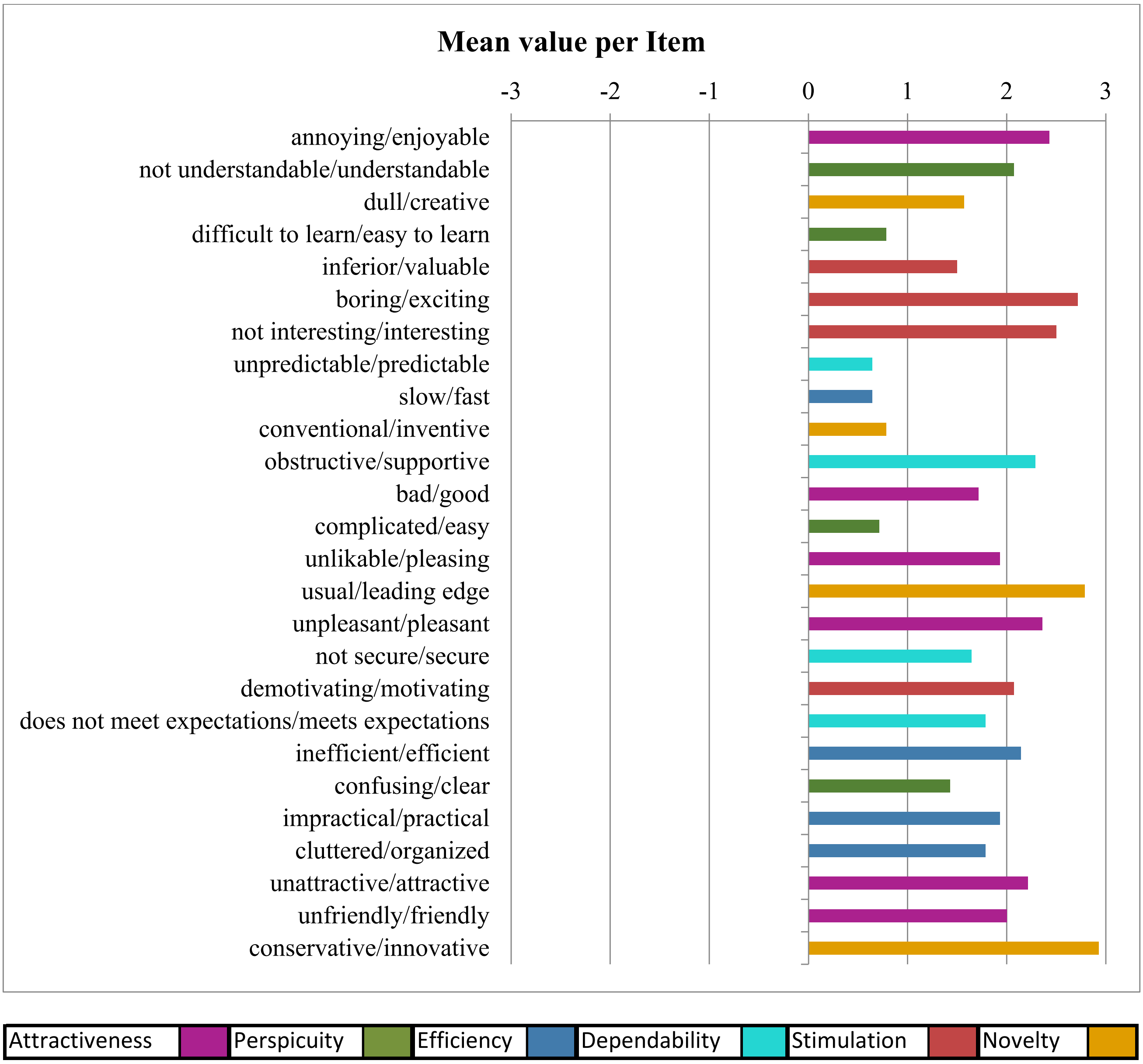

Figure 3. The UEQ results were collected across the participants. The mean value for each item assessing the quality has been plotted. The colour legend has been displayed below the figure. The colour coding refers to qualities which were grouped together under an overall quality. For example, attractiveness of the device was calculated using annoying/enjoyable, bad/good, unlikeable/pleasing, unattractive/attractive, and unfriendly/friendly.

UEQ analysis was further grouped into pragmatic qualities such as perspicuity, efficiency, and dependability, as well as hedonic qualities such as stimulation and originality. Pragmatic describes task-related quality aspects while hedonic describes non-task related quality aspects. Table 1 and Figure 4 reflect the collective mean values attained from a score of −3 to +3 for items grouped together into Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty.

Table 1. Mean values for items grouped under Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty.

Scale	Mean	Comparison to Benchmark	Interpretation
Attractiveness	2.11	Excellent	In the range of the 10% best results
Perspicuity	1.25	Above Average	25% of results better, 50% of results worse
Efficiency	1.63	Good	10% of results better, 75% of results worse
Dependability	1.59	Good	10% of results better, 75% of results worse
Stimulation	2.20	Excellent	In the range of the 10% best results
Novelty	2.02	Excellent	In the range of the 10% best results

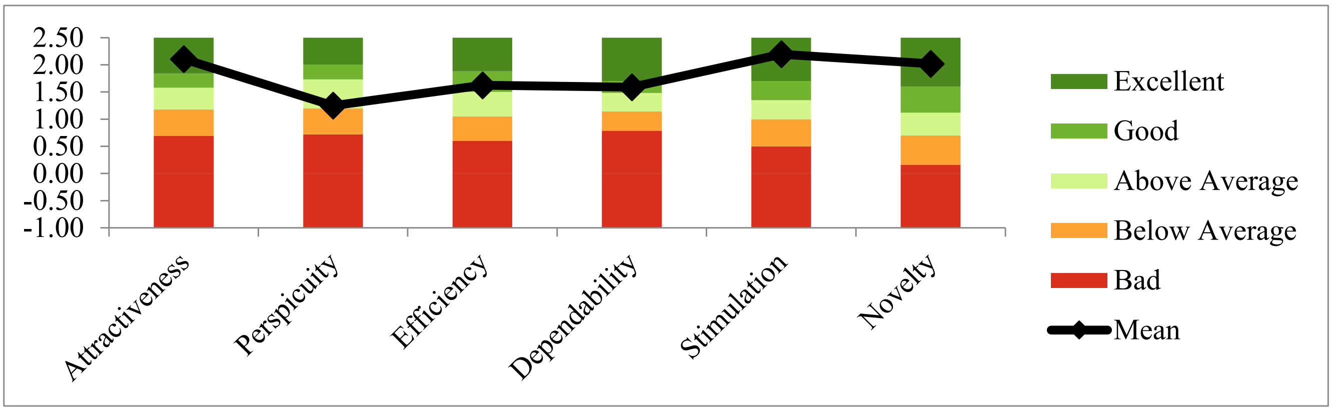

Figure 4. Mean values for items grouped under Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty.

Scores obtained on the UEQ revealed that MR technology is rated "Excellent" on quality aspects for Attractiveness, Stimulation and Novelty. However, it scored "Good" on Efficiency and Dependability, and only "Above average" in Perspicuity.

The second questionnaire focused on specific aspects of the utility of MR in education. A radar chart was used to represent the scores. The authors acknowledge that we have not conducted a serial assessment to see changes in this assessment over time. Given the nature of the questionnaire, the score was presented as a radar chart. Figure 5A,B presents the median scores for each of these domains. While a score of 7 was recorded for just over 50% of outcomes assessed, there were two key areas that highlighted room for further improvement.

The median score for participant's subjective rating of their learning curve for the use of HoloLens MR Technology was 5 out of 7. This ties in with the results from Figure 3 whereby speed of acclimatisation to MR technology was the most poorly scored domain. In addition to this, the median rating for ease of manoeuvring using the HoloLens slicer box for anatomy demonstration was 5.5, reflecting room for further improvements.

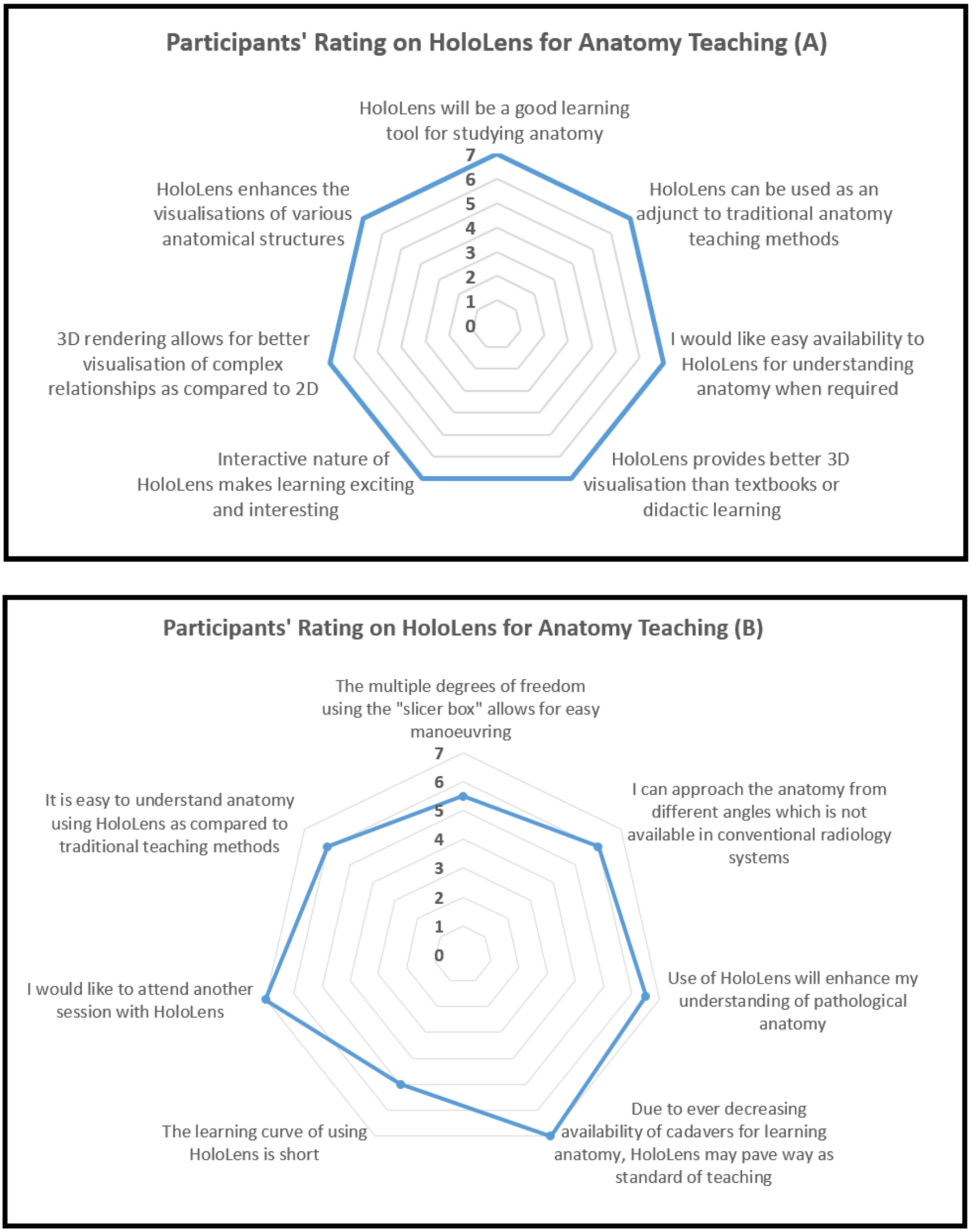

Figure 5. (**A**) Radar Chart depicting the distribution of median scores across various faculties evaluating the use of HoloLens MR Device in anatomy demonstration and teaching. (**B**) Radar Chart depicting the distribution of median scores across various faculties evaluating the use of HoloLens MR Device in anatomy demonstration and teaching.

5. Discussion

Recent times have seen a gradual shift away from didactic teaching across medical schools worldwide due to the availability, cost and time restraints of traditional methods [23]. This effect has been further potentiated following the COVID-19 pandemic, which led to a transition of medical education away from an in-person format towards an online model [9]. Therefore, concurrent technological advances have prompted the use of VR and MR software to supplement more traditional methods of [24]. There is well-established evidence to support that both MR and VR teaching provide high rates of satisfaction and acceptability as a supplementary education aid [25]. Our group has previously demonstrated that mixed reality can supplement highly focused teaching in neuroanatomy [8]. However, the question of whether this can be extrapolated to training the trainers to assist them in using MR in their endeavours remains unanswered.

MR technology provides an immersive experience, providing a platform to utilise different imaging modalities to view in a 3-dimensional space. The new headsets are easy to wear, light weight, and has been tried in myriads of non-educational uses [26]. This cross-sectional study provides insights into new user experience when viewing and manoeuvring more complex anatomical structures. Only 29% of the responders had previously used an MR device. In a 2-h session of implementing an MR-based device, the results of the UEQ were encouraging. The attractiveness, stimulation, and novelty were rated as excellent. To make MR a regular component in teaching, the trainers should not find the device obstructive or unpleasant to use. The high perspicuity score again reflected that the instructions to use the MR platform were clear and easy to learn.

The authors acknowledge that there was heterogeneity in the participant background (doctors, nurses, and allied health professionals) with varying clinical experience preventing us to generalise the results of this study. At the same time, the heterogenous cohort used this MR platform to visualise and interact with a set of images that was irrelevant to their clinical background. Extrapolating both subjective and objective feedback, the results highlight the ability to implement MR platform in routine teaching environments.

Using our previous experience [8], a modified questionnaire was used in understanding the utility of MR in anatomy teaching. Figure 5A,B provide insights into this. The interactive nature of the device and ability of the MR platform to provide 360 degrees of freedom, the participants rated the MR platform very highly where visualisation of the anatomical structures were concerned. As the authors did not focus on specific anatomical understanding in this study, we were unable to provide any results if it improved the understanding of the participants. In Figure 5B, one of the lowest scores was in the learning curve. This is not unexpected given lack of previous experience. Only 2 h were allocated for this study, which is likely insufficient to make a user proficient. Furthermore, different MR devices and software platforms may require different training times. Our study only presents the results using one platform. Training times may differ and institutions planning to implement this across different disciplines should take note that additional time is required to train the trainers in addition to developing content for MR platforms.

Whilst the authors predominantly looked at responses for "anatomical teaching", there are multiple other uses of MR. Trainers who may deal with procedures such as insertion of central venous catheters, arterial lines, and even intubation can put these devices to use to supplement teaching. By demonstrating the ease of learning in a diverse group of trainers, the authors highlight the ease with which MR can be introduced into a learning environment.

The number of publications evaluating the use of MR software in neurosurgery has exponentially increased within the last decade, primarily in the US, Canada, China and Germany [27]. While this degree of interest in MR is promising, it is important to evaluate whether the intended target audience will be receptive towards using this technology for education purposes. We acknowledge that our study lacks controls to compare trainers using other methods of teaching. There is minimal to no literature data available on using MR in training the trainers. Long term viability of persistent implementation of MR by trainers remains unassessed in our study. In the second questionnaire, a high median score of 7 was obtained when trainers were asked if they would like to attend another session with HoloLens. Our research highlights that along with the utility in learning, this is also a practical and easy-to-use modality, with trainers willing to adopt the technology despite the need to wear a head mounted device. This in turn also paves the way forward for future research on the implementation of MR across various domains.

Use of remote access of the MR technology provides an avenue for its utility in low-income countries [10]. It allows the trainers to teach the audience through repetition without requiring use of expensive simulation models or in cases where students are unable to access training due to geopolitical situations. Some audience verbalised about using MR-based platform to provide "virtual consults" or provide direct instructions to trainers without being present physically. The authors acknowledge that the session was too short to explore the remote connectivity of the MR device. However, the audience expressed their interest in the utilisation of MR device for remote access.

Subjective feedback from various participants highlighted the potential areas of use of MR in training. The most highlighted areas were remote learning, remote review of patients due to resource constraints, informed consent taking, and repetitive learning in absence of cadavers/stimulation sets. Several participants expressed their interest in research projects involving MR in education which was positive feedback given the very short training session utilised.

The course participants acknowledged that even if MR is unable to replace all the teaching methods, it will supplement training. The lack of cadavers for learning anatomy remained a great concern amongst the participants (Figure 5B), providing the trainers to look for other avenues for teaching, making MR attractive.

6. Conclusions

MR has become an attractive modality to be introduced in medical education and surgical training. However, current literature does not address the feasibility of training the future trainers in using MR platforms. The study evaluated the feasibility of introducing training sessions to use MR platforms in training the trainers. In an ever-changing era of remote learning, and lack of hands on cadaveric or expensive stimulation models, the positive objective and subjective feedback seen in this study was encouraging. Further studies are required to understand subject specific utility of MR and its viability in the long run.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app15052403/s1, Questionnaires SA and SB.

Author Contributions: Conceptualization, P.S.M., S.J., S.S.K. and A.H.; methodology, P.S.M., S.J. and S.S.K.; software, P.S.M. and S.J.; validation, P.S.M., S.J. and S.S.K.; formal analysis, P.S.M. and S.J.; investigation, P.S.M. and S.J.; resources, P.S.M., S.J., S.S.K. and A.H.; data curation, P.S.M. and S.J.; writing—original draft preparation, P.S.M. and S.J.; writing—review and editing, P.S.M., S.J., S.S.K. and A.H.; visualisation, P.S.M.; supervision, S.J., S.S.K. and A.H.; project administration, A.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are not directly available due to privacy concerns. The authors can be contacted if further information is needed.

Acknowledgments: We would like to thank the University of Cambridge and the University of Singapore for making this project possible. We also extend our gratitude to the ApoQlar Medical and Microsoft corporations for providing the technology required to execute this study.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

MR	Mixed reality
3D	Three-dimensional
UEQ	User Experience Questionnaire
AR	Augmented reality

References

1. Bracq, M.S.; Michinov, E.; Jannin, P. Virtual Reality Simulation in Nontechnical Skills Training for Healthcare Professionals. *Simul. Healthc. J. Soc. Simul. Healthc.* **2018**, *14*, 1. [CrossRef] [PubMed]
2. Dey, A.; Billinghurst, M.; Lindeman, R.W.; Swan, J.E. A Systematic Review of 10 Years of Augmented Reality Usability Studies: 2005 to 2014. *Front. Robot. AI* **2018**, *5*, 37. [CrossRef] [PubMed]
3. Wach, J.; Winkler, D.; Vychopen, M.; Kropla, F.; Grunert, R.; Güresir, E. Students' perspectives regarding needs for and opportunities with mixed-reality education in neurosurgery at German medical schools. *Neurosurg. FOCUS* **2024**, *56*, E17. [CrossRef] [PubMed]
4. Dhar, P.; Rocks, T.; Samarasinghe, R.M.; Stephenson, G.; Smith, C. Augmented reality in medical education: Students' experiences and learning outcomes. *Med. Educ. Online* **2021**, *26*, 1953953. [CrossRef]
5. Barteit, S.; Lanfermann, L.; Bärnighausen, T.; Neuhann, F.; Beiersmann, C. Augmented, Mixed and Virtual Reality-based Head-Mounted Devices for Medical Education: A Systematic Review (Preprint). *JMIR Serious Games* **2021**, *9*, e29080. [CrossRef] [PubMed]
6. Aoyama, R.; Anazawa, U.; Hotta, H.; Watanabe, I.; Takahashi, Y.; Matsumoto, S. The Utility of Augmented Reality in Spinal Decompression Surgery Using CT/MRI Fusion Image. *Cureus* **2021**, *22*, e18187. [CrossRef] [PubMed]
7. Dadario, N.B.; Quinoa, T.; Khatri, D.; Boockvar, J.; Langer, D.; D'Amico, R.S. Examining the benefits of extended reality in neurosurgery: A systematic review. *J. Clin. Neurosci.* **2021**, *94*, 41–53. [CrossRef] [PubMed]
8. Jain, S.; Timofeev, I.; Kirollos, R.W.; Helmy, A. Use of Mixed Reality in Neurosurgery Training: A Single Centre Experience. *World Neurosurg.* **2023**, *176*, e68–e76. [CrossRef] [PubMed]
9. Taylor, L.; Dyer, T.; Al-Azzawi, M.; Smith, C.; Nzeako, O.; Shah, Z. Extended reality anatomy undergraduate teaching: A literature review on an alternative method of learning. *Ann. Anat.—Anat. Anz.* **2022**, *239*, 151817. [CrossRef] [PubMed]
10. Kubben, P.; Sinlae, R.S.N. Feasibility of using a low-cost head-mounted augmented reality device in the operating room. *Surg. Neurol. Int.* **2019**, *10*, 26. [CrossRef] [PubMed]
11. Suresh, D.; Aydin, A.; James, S.; Ahmed, K.; Dasgupta, P. The role of augmented reality in surgical training: A systematic review. *Surg. Innov.* **2022**, *30*, 366–382. [CrossRef] [PubMed]
12. Logishetty, K.; Western, L.; Morgan, R.; Iranpour, F.; Cobb, J.P.; Auvinet, E. Can an Augmented Reality Headset Improve Accuracy of Acetabular Cup Orientation in Simulated THA? A Randomized Trial. *Clin. Orthop. Relat. Res.* **2019**, *477*, 1190–1199. [CrossRef] [PubMed]
13. Sun, P.; Zhao, Y.; Men, J.; Ma, Z.-R.; Jiang, H.-Z.; Liu, C.-Y.; Feng, W. Application of Virtual and Augmented Reality Technology in Hip Surgery: Systematic Review. *J. Med. Internet Res.* **2023**, *25*, e37599. [CrossRef] [PubMed]
14. Bui, T.; Ruiz-Cardozo, M.A.; Dave, H.S.; Barot, K.; Kann, M.R.; Joseph, K.; Lopez-Alviar, S.; Trevino, G.; Brehm, S.; Yahanda, A.T.; et al. Virtual, Augmented, and Mixed Reality Applications for Surgical Rehearsal, Operative Execution, and Patient Education in Spine Surgery: A Scoping Review. *Medicina* **2024**, *60*, 332. [CrossRef] [PubMed]
15. Luciano, C.J.; Banerjee, P.P.; Bellotte, B.; Oh, G.M.; Lemole, M.; Charbel, F.T.; Roitberg, B. Learning Retention of Thoracic Pedicle Screw Placement Using a High-Resolution Augmented Reality Simulator with Haptic Feedback. *Oper. Neurosurg.* **2011**, *69*, ons14–ons19. [CrossRef] [PubMed]
16. Ghaednia, H.; Fourman, M.S.; Lans, A.; Detels, K.; Dijkstra, H.; Lloyd, S.; Sweeney, A.; Oosterhoff, J.H.; Schwab, J.H. Augmented and virtual reality in spine surgery, current applications and future potentials. *Spine J.* **2021**, *21*, 1617–1625. [CrossRef]

17. Li, W.; Liu, Y.; Wang, Y.; Zhang, X.; Liu, K.; Jiao, Y.; Zhang, X.; Chen, J.; Zhang, T. Educational value of mixed reality combined with a three-dimensional printed model of aortic disease for vascular surgery in the standardized residency training of surgical residents in China: A case control study. *BMC Med. Educ.* **2023**, *23*, 812. [CrossRef] [PubMed]
18. Ayoub, A.; Pulijala, Y. The application of virtual reality and augmented reality in Oral & Maxillofacial Surgery. *BMC Oral Health* **2019**, *19*, 238.
19. Mishra, R.; Narayanan, M.D.K.; Umana, G.E.; Montemurro, N.; Chaurasia, B.; Deora, H. Virtual Reality in Neurosurgery: Beyond Neurosurgical Planning. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1719. [CrossRef] [PubMed]
20. Papalois, Z.-A.; Aydın, A.; Khan, A.; Mazaris, E.; Rathnasamy Muthusamy, A.S.; Dor, F.J.; Dasgupta, P.; Ahmed, K. HoloMentor: A Novel Mixed Reality Surgical Anatomy Curriculum for Robot-Assisted Radical Prostatectomy. *Eur. Surg. Res.* **2021**, *63*, 40–45. [CrossRef]
21. Alfalah, S.F.M. Perceptions toward adopting virtual reality as a teaching aid in information technology. *Educ. Inf. Technol.* **2018**, *23*, 2633–2653. [CrossRef]
22. UEQ. User Experience Questionnaire (UEQ) [Internet]. *Ueq-online.org*. 2018. Available online: https://www.ueq-online.org/ (accessed on 2 January 2025).
23. Kochhar, S.; Tasnim, T.; Gupta, A. Is cadaveric dissection essential in medical education? A qualitative survey comparing pre-and post-COVID-19 anatomy courses. *J. Osteopath. Med.* **2023**, *123*, 19–26. [CrossRef] [PubMed]
24. Silvero-Isidre, A.; Friederichs, H.; Müther, M.; Gallus, M.; Stummer, W.; Holling, M. Mixed Reality as a Teaching Tool for Medical Students in Neurosurgery. *Medicina* **2023**, *59*, 1720. [CrossRef]
25. Hey, G.; Guyot, M.; Carter, A.; Lucke-Wold, B. Augmented Reality in Neurosurgery: A New Paradigm for Training. *Medicina* **2023**, *59*, 1721. [CrossRef] [PubMed]
26. Birlo, M.; Edwards, P.J.E.; Clarkson, M.; Stoyanov, D. Utility of Optical See-Through Head Mounted Displays in Augmented Reality-Assisted Surgery: A systematic review. *Med. Image Anal.* **2022**, *77*, 102361. [CrossRef] [PubMed]
27. Cannizzaro, D.; Zaed, I.; Safa, A.; Jelmoni, A.J.M.; Composto, A.; Bisoglio, A.; Schmeizer, K.; Becker, A.C.; Pizzi, A.; Cardia, A.; et al. State of Art and Future Projections. A Systematic Review. *Front. Surg.* **2022**, *9*, 864792. [CrossRef] [PubMed]