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Indonesian Medical Lecturers' and Students' Awareness, Perception, and Readiness Towards Extended Reality in Medical Education

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ABSTRACT

Extended reality (XR) has become one of the most promising tools for supporting learning and practice in medicine, especially in countries with limited resources such as Indonesia. This study assessed medical lecturers' and students' awareness, perceptions, and readiness to implement XR in Indonesian medical education. We conducted a cross-sectional study of multiple medical schools across Indonesia from April to May 2021. Our respondents were lecturers and students from the undergraduate and postgraduate stages of medical faculty. Respondents were asked to complete a self-constructed questionnaire with 40 questions for lecturers and 31 for students. A total of 415 respondents, comprising 246 undergraduates, 96 postgraduates, and 73 medical lecturers from 34 medical faculties and 28 provinces in Indonesia, participated in the survey. Most medical lecturers and students were aware of the XR system, with Virtual Reality (VR) being the most common type of XR reported (72–76%). However, most students and lecturers had no experience utilising XR technology (58–65%). The use of VR was the highest among all types of XR technology (29–37%), while MR was the lowest (2–3%). Most respondents reported an interest in medical training using XR facilities (89–97%). However, they also expressed concerns about potential adverse effects and a lack of confidence that the Indonesian medical faculty was ready for XR implementation. The results showed positive awareness and perceptions of XR in Indonesian medical education. Further studies are required to fully assess the need for the XR system across different stages of medical education.

Keywords: *extended reality, medical education, awareness, perceptions, readiness*

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INTRODUCTION

Recent developments in information technology, 5G internet connection, artificial intelligence, and computer power have made it possible to perceive and experience reality in novel ways.(1) These advancements have paved the way for users to be fully immersed in computer-generated environments, known as extended reality (XR), where they can actively participate and engage as part of a digital world or seamlessly interact with the digitally enhanced real world through smartphones or specialised glasses.(2) The term XR refers to a broad spectrum of technologies, ranging from augmented reality (AR) to virtual reality (VR).(3) AR technology integrates computer-generated objects and virtual content into the real world.(4) Digital content can be accessed directly using a head-mounted display (HMD), smart glasses, or indirectly through a mobile phone display. In contrast, VR technology blocks users' real-world perception through the use of a head-mounted display with head-tracking systems, navigational aids, haptics, and sound systems.(5) Finally, mixed reality (MR) blends augmented virtuality and AR into one emergent technology.(6)

XR has become one of the most promising potential tools for supporting learning and practice due to its improved portability, realism, and real-time navigation, extending the variety of user feelings with sensory and motoric components.(7) Voice and gestural inputs allow for more interactive learning experiences.(8) XR's ability to create real-world perception could produce real-life scenarios and consequences based on students' actions, creating a more engaging learning experience (9,10). Moreover, immersive simulation-based training could accelerate the learning curve and minimise malpractice and its impact on patients.(11,12) In addition, XR-adapted gamification of learning activities can create exciting and fun learning activities (13), improving students' motivation and interest (14), knowledge (15), engagement (16), study results (17,18), and satisfaction.(19)

XR has the potential to significantly change how medical topics are taught. It offers the possibility of reducing the use of traditional medical learning resources, such as cadavers and other skill lab tools, which may be subject to financial, ethical, and administrative constraints.(20-22) Students can use XR to study anatomy and physiological processes examining the simulated human body. Magnetic resonance imagings (MRIs) and Camputed Tomography (CT) scans, which are unique to patients, can be integrated with XR simulations along with other digital biomedical data.(3) Herron summarised the benefits of XR in medical service and education based on several previous studies, which included reducing the required practice time, supporting telemedicine, and providing real-time feedback.(23) Repetition is one of the many XR benefits. While XR encourages students to improve their skills by performing tasks repeatedly, it also allows repeated tasks to be automated and reduces users' boredom while performing such tasks.(24, 25) Overall, XR implementation would benefit the quality of education, especially in areas with limited resources and support institutions, helping to produce competent medical practitioners.(22)

Despite XR's potential benefits, immersive technology development requires a large allocation of institutional resources, especially time and funds.(26) XR development without detailed blueprints could result in nonoptimal XR usage and learning outcomes. Barsom et al. highlighted the need to establish the validity of such technologies, for example, by examining the ability of the technology to predict its actual future efficacy. Students' performance while using XR needs to be equivalent to their performance in the real world.(27) One of the early steps to ensure the values and use of such technologies involves exploring the acceptance of the main stakeholders, that is, medical students and lecturers.(28) There are few measurement tools for assessing the readiness of lecturers or students to implement XR. Huang et al. developed an instrument to measure students' readiness for VR learning.(28) Further, Jwaifell assessed lecturers' readiness using a tool based on the technological, pedagogical, and content knowledge (TPACK) domains.(29)

Adopting XR within Indonesian medical faculties holds great significance, particularly in addressing the challenges posed by limited resources. The integration of XR as a part of the learning tools in medical education offers a remarkable opportunity to establish effective distance learning programs for remote medical faculty and health practitioners across Indonesia. XR adoption would enable individuals in remote areas to access high-quality education and training, thus bridging the gap created by geographical constraints. However, despite the accelerating development of XR technology, there is a notable absence of studies examining the perceptions and readiness of medical lecturers and students regarding implementing XR in Indonesian medical education. XR utilisation without considering users' perceptions and intentions to use XR could limit users' acceptance of the XR technology. Based on technology acceptance model (TAM) theory, these could also affect the effectiveness and efficiency of XR, as individuals' attitudes towards a specific technology influence how well they perform when using it.(28) In order to prevent costly development without real benefits to medical education, a study examining the perceptions of Indonesian medical lecturers and students regarding XR is crucial. Accordingly, this study aimed to assess medical lecturers' and students' awareness of, perceptions regarding, and readiness to implement XR in Indonesian medical education.

METHODS

Ethics statement

The Health Research Ethics Committee of the Faculty of Medicine Universitas Indonesia and Cipto Mangunkusumo Hospital (HREC-FMUI/CMH) approved this study (KET-1489/UN2.F1/ETIK/PPM.00.02/2020). Respondents received an informed permission form and questionnaire through the Electronic Data Capture Faculty of Medicine Universitas Indonesia (REDCap UI). Respondents' responses were anonymous to maintain their privacy and confidentiality.

Study design and participants

In this cross-sectional study, we employed a self-constructed questionnaire to evaluate medical students' and lecturers' awareness of, perceptions regarding, and readiness to implement XR in medical education. The study was conducted within the Faculty of Medicine at Universitas Indonesia, with data collection occurring between April and May 2021. To ensure a diverse pool of respondents, we utilised various communication channels, including personal email, professional organisation chat groups, and social media platforms, to distribute and promote the recruitment survey.

The participants in this study encompassed medical students in different stages of education, including undergraduate students and postgraduate students engaged in internship, residency, or master's programmes. Furthermore, we extended the invitation to medical lecturers, thus incorporating their valuable insights and perspectives. It is worth noting that Indonesia boasts a significant number of medical schools — currently, there are more than 100 such institutions spread across 38 provinces. By considering participants from multiple institutions, we aimed to capture a broader representation of the medical education landscape within the country.

Questionnaire

Medical lecturers and students were invited to answer 40 (the lecturer questionnaire) or 31 questions (for students). We used a self-constructed questionnaire. The questionnaire content was arranged based on literature reviews and reviewed by experts in medical education and medical technology. The questionnaire is reported as an additional file (see Supplementary File 1). Specifically, the lecturers' questionnaire included 16 questions about lecturers' characteristics, seven about internet utilisation, and 17 about their awareness of, experiences and perceptions regarding, and readiness to implement XR for medical education. In comparison, the student questionnaire included ten questions about students' characteristics, seven about internet utilisation, and 14 about their awareness of, experiences and perceptions regarding, and readiness to implement XR for medical education. Several items were graded using a six-point Likert rating scale. Im the quantitative analysis, the answers were coded as followed: 1 = 'strongly disagree', 2 = 'moderately disagree', 3 = 'slightly disagree', 4 = 'slightly agree', 5 = 'moderately agree', and 6 = 'strongly agree'. Average scores were calculated for each question, and a value >4 was considered a positive response.

Statistical Analysis

This study utilised a voluntary online survey to assess medical lecturers' and students' awareness of, perceptions regarding, and readiness to implement XR in Indonesian medical education. Therefore, no specific sampling methods were used to determine the exact number of respondents. Rule-of-thumb methods were used to estimate the minimum sample size (30 respondents). We reported each question in percentages and then represented them in bars. Microsoft Excel® v.365 was used in the statistical analyses.

RESULTS

Participants

Of 734 respondents, 415 (56%) completed the questionnaire. A total of 342 (82%) respondents were medical students, while 73 (17%) were lecturers. We recorded 34 (41%) out of 83 medical faculties and 28 (74%) from 38 provinces in Indonesia. Thirty-two per cent of respondents were male, 67% were female, 17% were medical lecturers, 59% were undergraduate students, and 23% were postgraduate students. Approximately 20% of lecturers obtained their degrees abroad.

Most lecturers teach in classrooms (89%). Table 1 presents the respondents' demographic characteristics.

Table 1: Respondent demographic characteristics

Demographic characteristics	n (%)
Educational stage	
Undergraduate	246 (59.3)
Postgraduate	96 (23.1)
Lecturer	73 (17.6)
Gender	
Male	136 (32.8)
Female	279 (67.2)
Medical faculty origin	
Sumatera	130 (31.3)
Java	179 (43.1)
Bali, East Nusa Tenggara, West Nusa Tenggara	22 (5.3)
Borneo	25 (6.0)
Sulawesi	58 (14.0)
Maluku, Papua	1 (0.3)
Lecturer Profile (n=73)	
Studied abroad	
Yes	15 (20.5)
No	58 (79.5)
Teaching experience (years, mean±SD)	12.25 ± 7.3
Audience	
Pre-clinical phase student	68 (93.2)
Clinical phase student	35 (47.9)
Master's student	16 (21.9)
Resident doctor	22 (30.1)
Teaching location	
Classroom	65 (89.0)
Skills lab	54 (74.0)
Laboratory	37 (50.7)
Community	12 (16.4)
Hospital	23 (31.5)

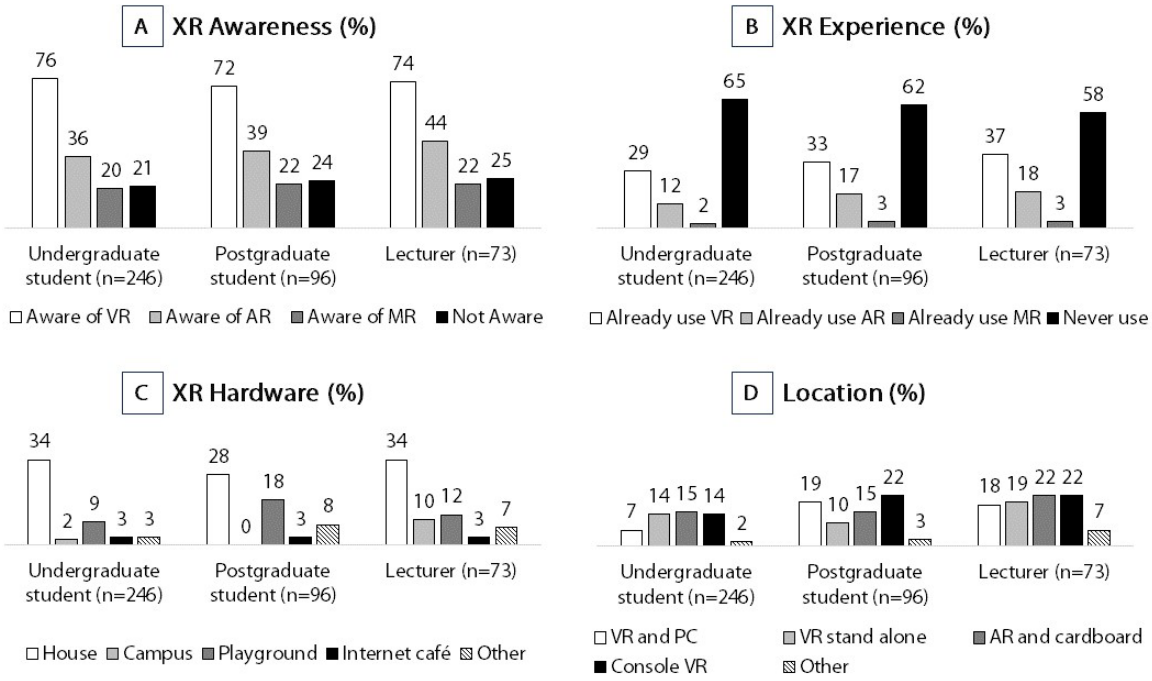
Internet Utilisation

Most lecturers indicated they use tablets (93%). Conversely, students reported a preference to use smartphones (90%). Regarding internet access, internet subscription rates were higher among lecturers (89%), while data package use (77.8%) was higher among students. The majority of respondents, both lecturers and students, reported using Indihome (64% and 64%, respectively), with speeds of 11–20 Mbps (45% and 34%, respectively). Like the lecturers, the students spent $7–20 to buy a monthly data package (46% and 41%, respectively). Students indicated that they access the internet longer (8–12 h, 37%) than lecturers (4-7 h, 38%). Most

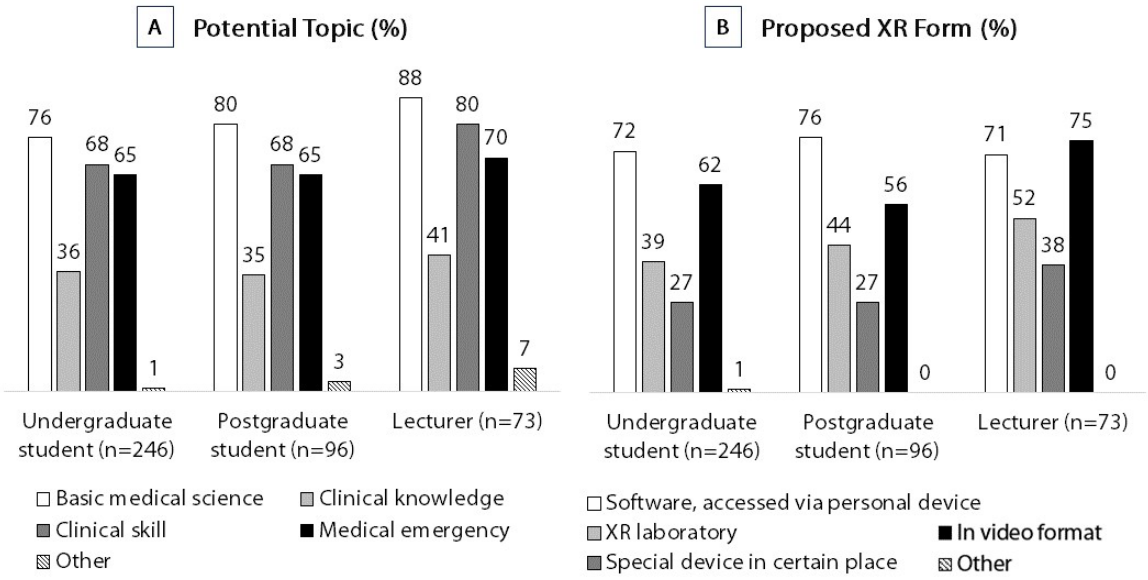
lecturers and students used the internet to browse information (83% and 90%, respectively) and access social media (82% and 90%, respectively).

XR awareness, experience, perception, and readiness

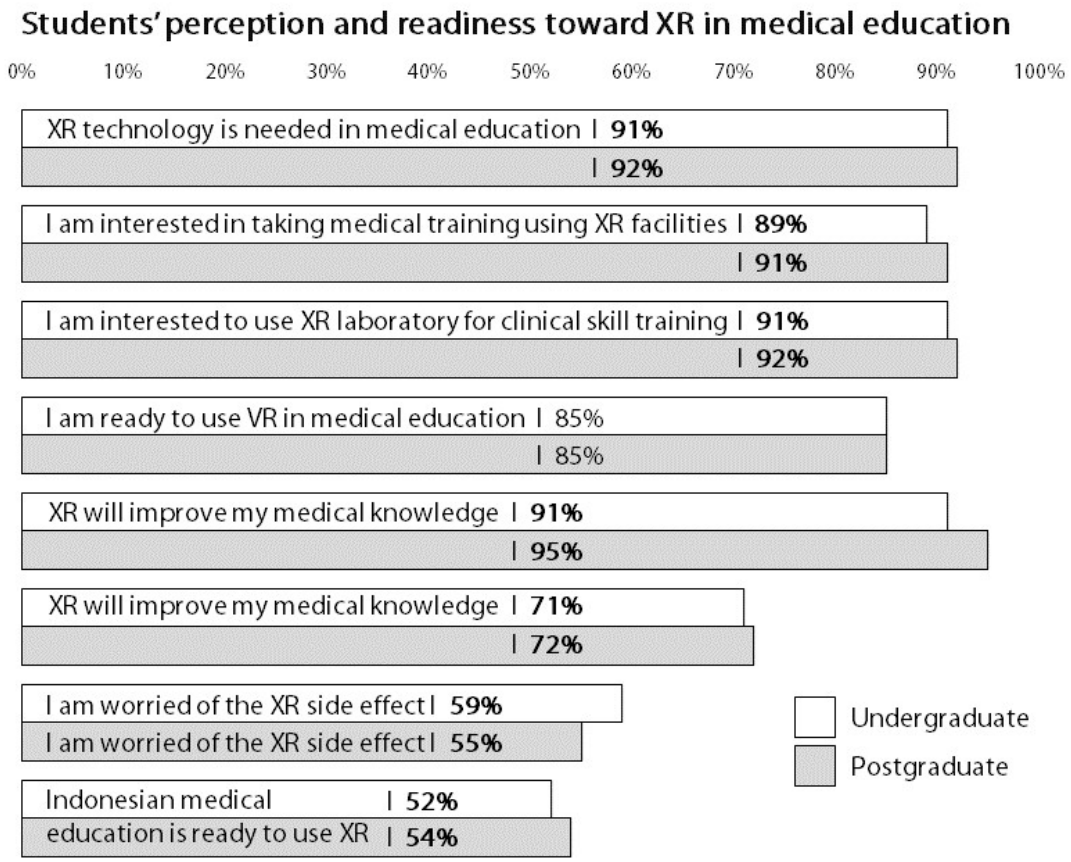
The proportion of respondents who were unaware of all types of XR was between 21% and 25%. Most respondents (72–76%) already knew about VR, but less than 50% knew about AR/MR (Figure 1A). Most respondents (58–65%) had no experience using XR. Approximately 37% of the lecturers already had experience in using VR, which was higher than undergraduate (29%) or postgraduate students (33%). Only 2–3% of our respondents have used MR (Figure 1B). Most undergraduate students have used mobile VR/AR (15%), VR plus console (14%), and stand-alone VR (14%), while postgraduate students have used game consoles (22%), computers/laptops (19%), and mobile VR/AR (15%) (Figure 1C). Among undergraduate and postgraduate students and lecturers, XR was mainly used in houses (28–34%) or on playgrounds (9–18%). The use of VR on campus was higher among lecturers (10%) than among undergraduate (2%) and postgraduate students (0%) (Figure 1D).



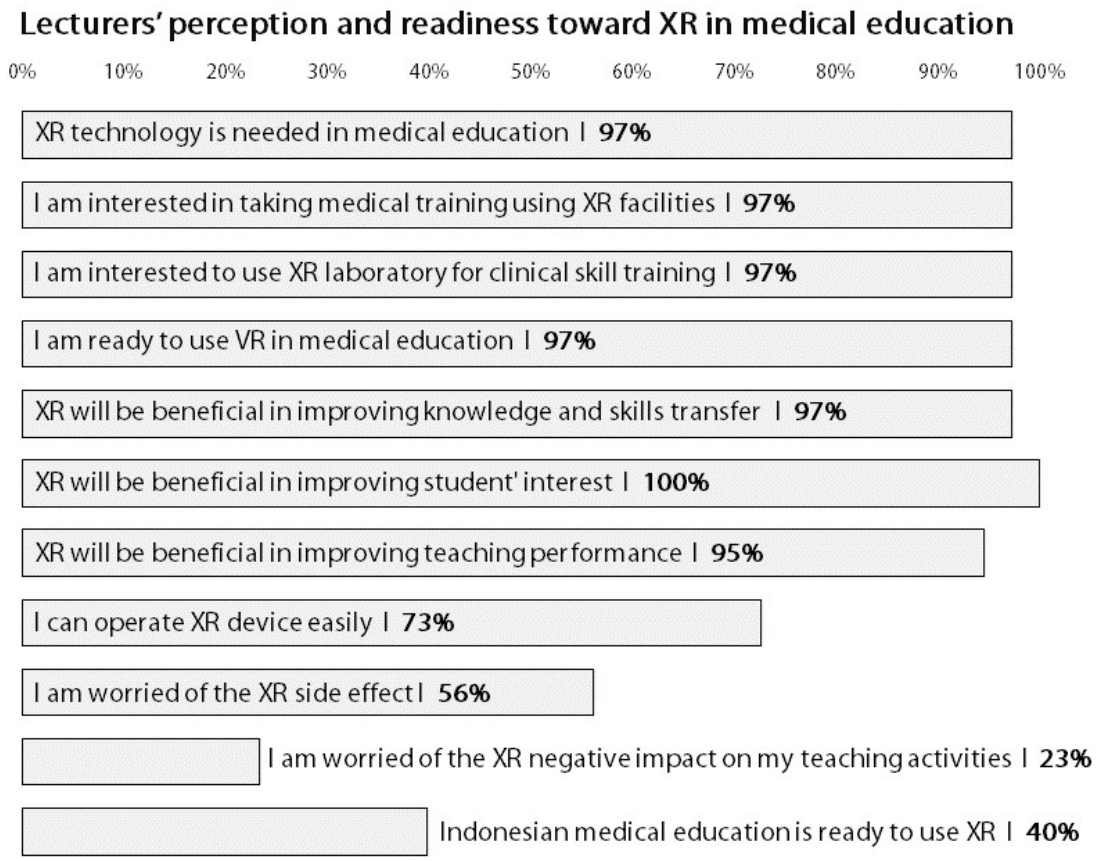
The majority of respondents (76–88%) suggested that basic biomedical science was the topic with the most potential for XR development, followed by clinical skills (68–80%) and medical emergencies (65–70%) (Figure 2A). The most popular form of XR for undergraduate and postgraduate students was software that could be accessed via personal devices (72% and 76%, respectively), followed by VR in a video format (56% and 62%, respectively). However, among lectures, VR in video format was rated the most popular (75%) (Figure 2B).



The majority of students showed an interest in using XR laboratory facilities (91–92%) or XR-based medical training (89–91%) if such facilities are available in their cities. They also believed that XR will be beneficial for improving knowledge (85–95%) and were confident that they could operate XR easily (71–72%). Nevertheless, there were concerns regarding motion sickness as a potential effect of XR (55–59%) and the lack of readiness to implement XR in Indonesia (52–54%) (Figure 3).



Most lecturers showed an interest in using XR-based medical training (97%) and XR laboratory facilities (97%). Moreover, they believed that XR will be beneficial in improving students' knowledge and skills (97%) and interest in lectures (100%), teaching performance (95%), and increasing the speed of knowledge and skills transfer (97%). Further, they were confident that they could operate XR easily (73%). However, lecturers expressed concerns regarding motion sickness as a side effect of XR (56%), potential negative impacts of XR on the teaching process (23%), and a lack of readiness to implement XR in Indonesia (40%) (Figure 4).



DISCUSSION

The use of XR in education has been extensively studied worldwide. However, the utilisation of XR as a learning tool in Indonesian medical education is still in an early phase. Most XR products provide information and knowledge outside medical topics, such as natural science (30) and tourism (31), or are used as part of clinical management, such as pain relievers.(32) Several papers have introduced XR applications (33-35), but they have yet to be commercially distributed or widely implemented in Indonesian medical curricula. Furthermore, we found no valid method for evaluating the need for XR development based on the Indonesian medical faculty setting, highlighting the need to start an explorative XR study by assessing the acceptance of the main stakeholders of XR technologies in Indonesia. Thus, this study first described medical students' and lecturers' awareness of, perceptions regarding, and readiness to implement XR in Indonesian medical education. Our results showed that undergraduate, postgraduate, and lecturers have similar levels of XR awareness, with VR being the most common type of XR reported (72–76%). However, most students and lecturers do not have any experience in utilising XR technology (58-65%). The study also revealed that most Indonesian students and lecturers positively perceive XR usage in medical learning activities and believe that XR can increase medical knowledge. XR side effects are a significant concern reported by more than half Indonesian medical students and lecturers (55–59%). Ultimately, our respondents suggested that Indonesia was still not ready to implement XR in medical education.

Smartphones were the most common device Indonesian respondents use to access the internet. In a survey of 605 respondents, Puspitasari and Ishii revealed that internet access was higher on mobile phones (68%) than on PCs (53%). This study also found that Indonesian respondents spent $4–$7.1 for a monthly data package. It has been reported that most smartphone users use their internet access for entertainment.(36) This result is similar to most of our results, except that lecturers reported a preference for tablets over smartphones. Tablets have larger displays that help older people complete digital tasks like reading and typing.(37) Although we did not further explore the correlation between internet utilisation and XR awareness, some studies have highlighted the importance of internet use to XR implementation. Alalwan et al. reported that limited internet connectivity would hamper teaching and learning activities using XR.(38) However, with the extensive use of smartphones over PCs could be a reason to develop educational smartphone based-XR over standalone XR. The high accessibility of smartphone-based XR aligns with the growing trend of anytime and anywhere learning process.(39) Additionally, since the utilisation of smartphone-based XR requires no additional hardware, it could be a solution for both personal and institutional XR hardware procurement problems.(40)

Extended reality ranges from AR to VR, with MR in the middle of the continuum.(8) This terminology leads to ambiguity and confusion, especially for naïve users who have not used an XR system or who cannot recognise and distinguish the differences. This contradiction is also found in the way in which scholars define MR. Wedel et al. defined MR as a combination of VR and AR.(41) Conversely, Flavian et al. offered a different definition of MR being a combination of AR and augmented virtuality (AV).(42) Some factors triggering this ambiguity relate to producer profit and user satisfaction.(43) In our study, unclear boundaries and definitions led to low AR and MR awareness (<50%) and experience (<20%). These rates are similar to those for respondents who were unaware of XR (21–25%). We also found that many respondents had never experienced XR (58–65%). They may not recognise AR features in games or social media. Similar to our findings, De Ponti et al. found that a significant number of respondents had never used XR. Specifically, only 10% had used VR simulation, while 14% had used both VR and physical mannequins.(44) Increasing awareness regarding XR could be the first challenge if a medical faculty plans to use XR as a future learning tool. Seminars and workshops play an important role in introducing and providing a deeper understanding of new topics (45), and this is especially true for XR and its use in a medical education context. Thus, medical faculty seeking to introduce XR to their communities should invest heavily in such efforts.

Although less than 50% of the respondents had experienced XR in actual practice, both medical students and lecturers expressed positive perceptions of XR. Most published studies have shown a positive perception towards XR technology in medical education. For example, Cheung et al. invited medical students to undergo VR training and then complete a feedback questionnaire. Sixty-five sixth-year medical students completed surveys. Most of them (92%) claimed the training was effective in helping them remember the specifics of the assignments, and 84% felt the training instructions were clear. In addition, VR technology was found to encourage learning (66%) and facilitate learning and engagement (80%).(46) De Ponti assessed 122 students' perceptions of virtual reality usage during the Covid-19 pandemic. Of the 94% of respondents who completed the survey, 90% rated VR training favourably, and 93% liked how the online training was organised. Furthermore, most participants thought the VR training platform was realistic in its depictions of the first clinical assessment, diagnostic activities, and treatment options (77%, 94%, and 81%, respectively). In addition, 84% of respondents felt that using this VR training in the future would be beneficial as a supplement to apprenticeship at the patient's bedside.(44) Based on TAM theory, positive perception would impact on the "intention to use" variable. This theory could also be applied to XR utilisation, suggesting that both lecturers and students must value XR in order to plan to make use of it in the educational context. In addition,

users who find XR to be an attractive learning tool are more likely to find XR useful and thus have an intention to utilise it.(28,47)

All forms of XR proved helpful in different situations related to teaching and learning, theoretical knowledge, and practising clinical skills. A review by Jiang et al. on 114 studies reported that the most widespread uses of VR include surgical VR simulators (60%), virtual worlds (17%), and 3D models for anatomy education (13%).(11) Further, a bibliographic study by Yeung revealed that VR and AR phrases were closely related to surgery phrase, such as laparoscopic skill (95/8399, CPP=29.9), surgical skill (190/8399, CPP=35.9), surgical training (195/8399, CPP=29.1), and surgical simulation (103/8399, CPP=26.5).(25) Contrary to our survey results, basic biomedical science ranks higher than clinical skills as the topic most requested for XR development. The difference could be that most of our respondents are undergraduate students and requested an XR application that could be accessed via a personal device. However, the availability of VR HMD, haptics, and any peripherals must be considered thoroughly, and the development of VR applications that could support learning clinical skills must be adapted to meet market needs.(48)

The adoption of XR offers tremendous potential, yet it necessitates careful consideration of potential side effects, which could lead to user apprehension. As a previous study has shown, side effects could raise concerns about implementing XR. Common complaints following XR experiences include issues like eye strain, headaches, and motion sickness.(48-50) In particular, motion sickness as a potential XR side effect was found to be a concern in the present study. This occurs when the vestibular system tells the body it is stationary while the visual system tells the body it is moving. This incongruence often leads to discomfort and disorientation.(51) Hardware, content, and human factors are the three variables that may lead to motion sickness.(49) To fully harness the benefits of XR while mitigating its potential drawbacks, it is imperative to delve deeper into the development of motion sickness prevention strategies and user-centric design principles, thus ensuring a more comfortable and immersive XR experience for all.

Readiness for XR implementation is an issue that was highlighted in this study. The lack of XR introduction for students and lecturers, high costs, and user experience contributed to the lack of readiness for XR implementation.(52) Furthermore, despite the trend of XR usage in various medical education sectors, the current XR application in Indonesia is still a prototype. Local hardware-based VR has yet to be developed or sold in the Indonesian market. As of 2023, there were still no VR hardware companies located in Indonesia. Meta, the biggest VR brand in Indonesia, has yet to open an official location. Nevertheless, with the development of 5G, VR technology, and VR companies in Indonesia, the need for VR in medical education will continue to grow. Data from Statista showed that the revenue generated by XR (hardware and software) will continue to advance from USD 312.20 in 2023 to USD 544.70 in 2027.(53) Due to this growth, the medical education VR market will shift toward more complex learning applications, whereas there have been only simple applications in the early adoption phase.

The positive perceptions regarding XR utilisation found in this study will support XR development in Indonesian medical education. However, the low readiness level of Indonesian respondents must be considered and represents an important concern to institutions before developing or implementing XR into their medical curricula. The results of this study only provide initial data and should be interpreted carefully due to their limited generalisability. Despite our efforts to ensure a diverse sample, the respondent pool in this study still represents a limitation. While we successfully recruited participants from more than 50% of the provinces in Indonesia, encompassing 28 provinces, it is worth noting that most respondents were concentrated in the most populated cities. This concentration of respondents from urban areas may introduce a potential bias and reduce the representation of perspectives from medical schools in rural or

remote regions. Regrettably, we encountered challenges in obtaining complete survey responses from medical schools located in rural areas. The low response rate from these regions could be attributed to limited internet access, logistical constraints, or a lack of awareness about the study. Consequently, the perspectives and experiences of medical students and lecturers from rural areas may be underrepresented in our findings. However, as this study is the first to examine Indonesian medical lecturers' and students' perceptions of and readiness to implement XR based on a large pool of respondents, the findings are still valuable.

Further studies should explore the correlation between internet utilisation and the awareness of, perceptions regarding, and readiness to implement XR among Indonesian medical lecturers and students. Future research on XR implementation in medical education should include relevant stakeholders, institutional culture, and government instruction as potential factors affecting medical lecturers' and students' awareness of, perception regarding, and readiness to implement XR. In addition, effective and efficient XR applications must also be responsive to national issues and needs regarding health problems. Otherwise, XR as a learning modality will not be able to help solve medical education problems in Indonesia.

CONCLUSION

Most medical students and lecturers are aware of and showed a positive perception towards the use of XR in Indonesian medical education. However, some XR side effects were a concern in XR implementation.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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