Extended Reality and Its Role in Medical Education: A Survey

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Abstract: As Extended Reality (XR) technologies become increasingly relevant in medical education, this cross-sectional survey at ICBAS investigated undergraduate medical students' perceptions of XR's usefulness, learning impact, and potential barriers. Results indicated generally favorable attitudes, especially in anatomy, surgery, and emergency medicine, where spatial comprehension and procedural skills are essential. Nonetheless, many respondents reported minimal prior interaction with XR, frequently linking it to gaming rather than education. Students expressed a preference for hands-on, purpose-driven applications. Perceptions varied by academic year: junior students valued XR for consolidating theoretical knowledge, whereas senior students highlighted its role in simulating clinical practice. A phased approach to curricular integration is advised, starting with basic XR literacy and progressing toward targeted, discipline-specific implementations.

1 Introduction

Extended Reality (XR), including Augmented (AR), Mixed (MR), and Virtual Realities (VR), offers immersive and interactive training for medical education Magalhães et al. (2024). While VR creates fully digital environments Hamad and Jia (2022), AR overlays virtual elements on the real world Hantono et al. (2018), and MR blends both for real-time interaction Tan et al. (2024). These characteristics help learners safely visualize anatomy and practice their clinical skills Tsang et al. (2022).

Given that traditional medical education faces challenges such as limited patient availability, ethical constraints, and disruptions like those caused by COVID-19 Gaur et al. (2020); Majumder et al. (2023), XR provides scalable, customizable simulations that enhance engagement and support experiential learning, leading to improved knowledge retention Buddy (2025); Parmaxi (2020).

However, adoption challenges remain, including cost, technical complexity, and student acceptance, which is crucial for successful integration Škola et al. (2024). Since attitudes toward XR are underexplored, this study aims to fill that gap and better align XR with the educational needs of future healthcare professionals.

2 Methodology

A survey was conducted among medical students at ICBAS. Using voluntary non-probabilistic sampling, the survey (adapted from Mergen et al. (2023)) collected data on students' familiarity with XR, perceived usefulness, accessibility, and willingness to integrate XR into their education.

Ethical and data protection approvals were secured to guarantee that participation was voluntary and anonymous, with no personal data collected throughout the answers gathering period. At the same time, a pilot study with 29 medical students from institutions outside of ICBAS was carried on, indicating, in the end, no irregularities or incoherencies with the survey.

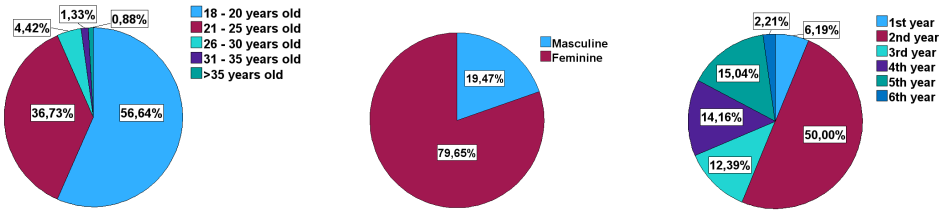
Analysis was done using IBM SPSS Statistics (v30). Descriptive statistics summarized responses by frequency and percentage, while inferential statistics tested associations between categorical variables. Chi-square tests ($p<0.05$) were primarily used, with Fisher's exact test or Monte Carlo's significance test applied when appropriate. Additionally, a word cloud summarized themes from the open-ended responses.

Limitations of this study include possible selection bias from voluntary sampling, the focus on a single institution which restricts generalizability, and a short data collection period.

3 Results

3.1 Sample and Demographics

A total of 226 undergraduate students, representing 20.75% of the medical program at ICBAS, completed the survey. Demographic data on age, gender, and study year are presented in Figure 1.



(a) Age. (b) Gender. (c) Study Year.

Figure 1: Demographic characteristics of the study's population.

3.2 XR Awareness and Prior Experience

Only 23.89% (n=54) of students were familiar with the term "Extended Reality (XR)", with males more likely than females to know it (29.55% vs. 21.67%, p=0.034).

Although the overall term was unfamiliar, awareness of individual XR technologies was higher (Figure 2): VR (93.36%, n=211), AR (56.19%, n=127), and MR (7.52%, n=17). Male students were more familiar with MR than females (15.91% vs. 5.00%, p=0.009). Most students (57.08%, n=129) could not distinguish between AR, MR, and VR, though this varied by study year (p=0.048), with 1st, 3rd, and 5th years showing higher familiarity.

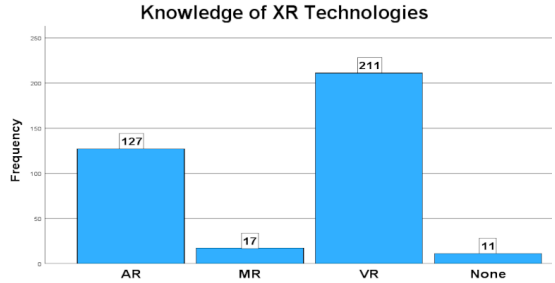


Figure 2: Self-reported awareness of XR's component technologies.

Only 21.68% (n=49) had used XR, mainly for gaming (59.18%, n=29), studies/profession (22.45%, n=11), or other purposes (18.37%, n=9). Males reported more experience than females (25.00% vs. 20.00%, p=0.047). Students familiar with XR were more likely to have prior experience (66.67%, n=36) than those unfamiliar (15.70%, n=27), a significant difference (p<0.001). Likewise, those who could distinguish AR, MR, and VR had higher rates of prior use (37.11%, n=36) than those who couldn't (10.08%, n=13) (p<0.001).

3.3 Perceived Utility and Format Preferences

Most participants (93.36%, n=211) viewed XR as a useful medical education tool, with only 6.64% (n=15) disagreeing.

Surgery was the top preferred clinical subject for XR integration (93.36%, n=211), followed by radiology (52.65%, n=119). Palliative medicine and pharmacology were less favored (all below 16%) (Figure 3).

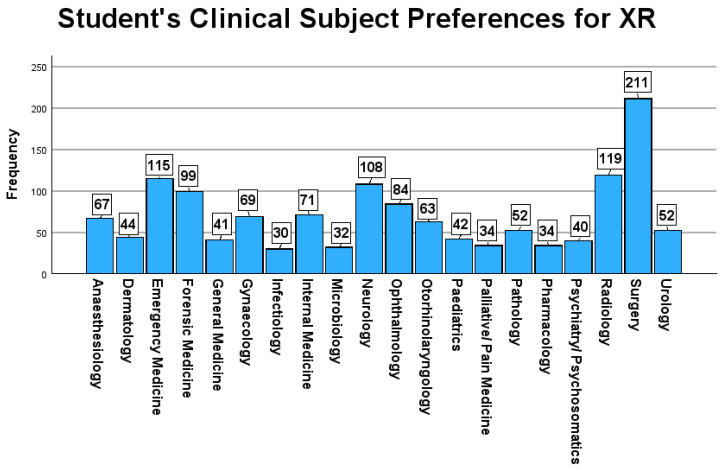


Figure 3: Preferred clinical disciplines for XR integration.

Age groups showed significant associations with preferences for anesthesiology (p<0.001), gynecology (p=0.031), emergency medicine (p<0.001), forensic medicine (p=0.001), and microbiology (p=0.041). The 21–25 age group was overrepresented in anesthesiology, emergency medicine, and gynecology, while younger students (aged between 18–20) were underrepresented. Study year also influenced preferences for anesthesiology, gynecology, emergency

medicine, and urology, with advanced students showing more interest. Belief in XR's successful integration correlated with higher interest in surgery (p=0.011).

For preclinical subjects, anatomy was the top choice (87.61%, n=198), followed by physiology (56.64%, n=128) and terminology (53.10%, n=120). Biochemistry, biology, and psychology/-sociology received the fewest votes (Figure 4).

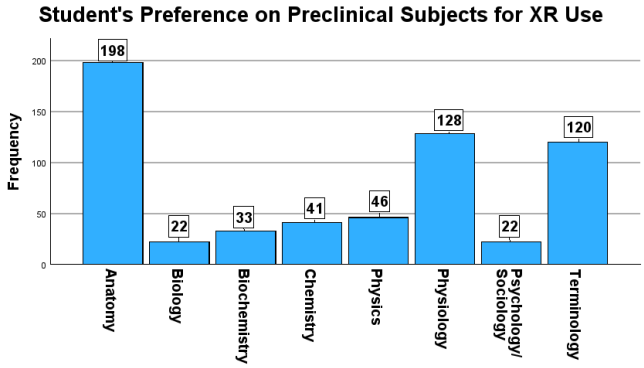


Figure 4: Student's preclinical disciplines choices for XR integration.

Gender was associated with anatomy preference (p=0.046), with males showing higher interest. Year of study correlated with preferences for physiology (p=0.045) and terminology (p=0.026), with distinct patterns across cohorts.

When it came to instructional formats, practical classes were favored by most students (82.74%, n=187), followed by seminars (12.83%, n=29) and theoretical classes (4.42%, n=10). Students skeptical of XR's usefulness preferred seminars and theoretical classes more than expected (p=0.036), while proponents favored practical classes.

For evaluation, nearly all respondents (96.46%, n=218) preferred practical exams for XR integration, with no significant associations found between variables and evaluation format choice.

3.4 Opportunities and Challenges of XR in Medical Education

Main potential advantages and disadvantages of integrating XR into medical education were also assessed (Figure 5). The top three chosen advantages were broad simulation possibilities (n=209, 92.48%), closely followed by interactive first-person learning (n=186, 82.30%), and competence improvements (n=166, 73.45%). The options of depiction of rare decisions (n=92, 40.71%) and repeatable scenarios (n=95, 42.04%) were less chosen, each with under 100 votes. Consequently, overall students only saw advantages on the integration of XR into their education, as "No Advantages" was only chosen three times (1.33%).

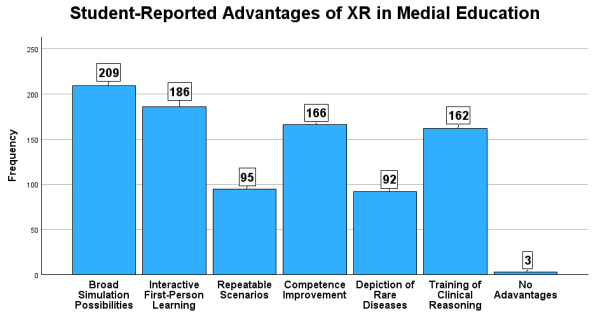


Figure 5: Advantages of XR in medical education as reported by students.

Most advantages showed no significant links to participant traits, except: depiction of rare diseases (p=0.020), higher agreement in 3rd (31.48%) and 4th years (53.13%), lower in 5th years (26.47%); better XR modality distinction linked to broader simulation (p=0.029) and competence gains (p=0.018); gaming experience linked to valuing repeatable scenarios (p=0.019); belief in XR success linked to broad simulation (p=0.018) and clinical reasoning (p=0.014); preference for practical exams linked to competence improvements (p=0.033).

Top chosen disadvantages included technical errors (62.39%), skill requirements (48.23%), health issues (32.74%), and unrealistic experiences (28.32%), with only 6.64% reporting no drawbacks (Figure 6). Age group significantly influenced concern over technical errors (p=0.011), with 18–20-year-olds selecting this more frequently (69.53%) than 21–25-year-olds (56.63%).

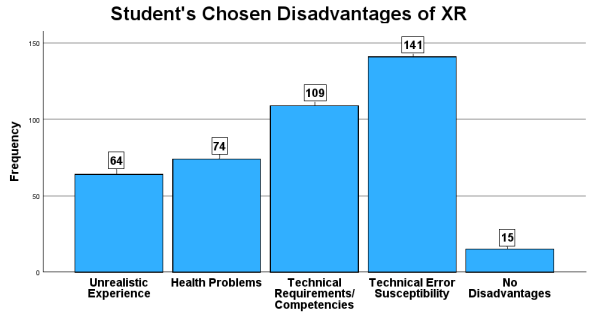


Figure 6: Student's reported disadvantages of XR technologies.

3.5 Attitudes Towards XR in Medical Education

In the final set of close-ended items, participants rated nine statements on XR's benefits, curricular integration, and clinical applications using a 5-point Likert scale (from 1 = "Definitely Not" to 5 = "Definitely Yes") (Figure 7). Most students believed XR would improve education (n=197, 87.17%) and expressed interest in XR-based courses (n=212, 93.81%). Many considered XR applicable to visual (n=178, 78.76%) and clinical (n=160, 70.80%) exams, though fewer envisioned its use for patient communication (n=78, 34.51%). Agreement for XR in teamwork and holistic simulations reached 63.72% (n=144).

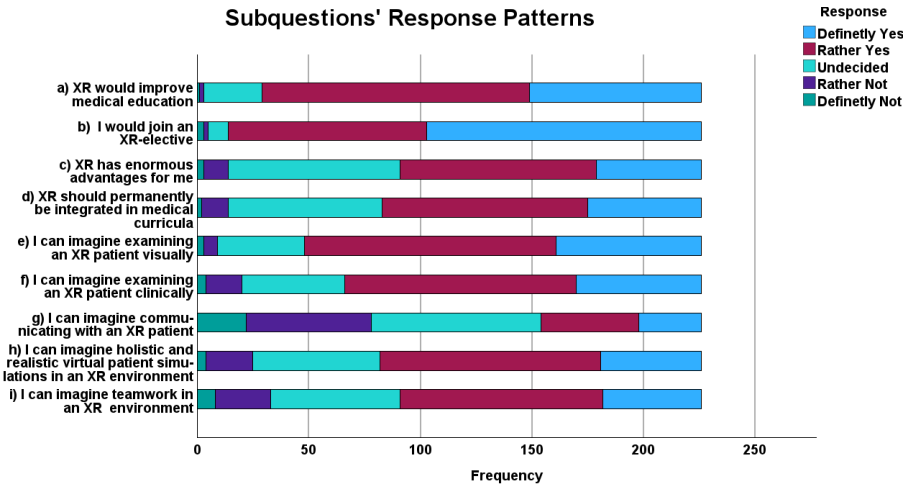


Figure 7: Distribution of responses across survey items rated on a 5-point Likert scale.

Gender influenced responses: females favored XR improving education (p=0.029), males more often chose "Definitely Yes" for item i) (p=0.039). Year affected views: 1st years "Definitely Yes," 2nd years undecided, 4th years "Rather Not" (item b), p=0.041); item c) showed polarized opinions across years (p=0.017). Confidence in XR integration correlated with positive responses (p<0.001). Class and exam format preferences shaped responses: practical-class/exam supporters were most positive, theoretical-class/exam supporters undecided, and seminar-preferring students moderately supportive (p=0.002–0.036). Exam format showed a similar pattern: practical exam preferrers were most positive about XR, while theoretical exams ones were more uncertain (p=0.003-0.004). Additionally, on a 0–10 scale, 84.1% rated XR's impact 7 or higher, mostly 7–10. Those without XR experience gave mid-range scores; experienced students favored 8–9. Seminar and theoretical learners rated lower; practical class supporters gave the highest scores.

3.6 Proposed XR Scenarios in Medical Education

The final survey question asked for XR application suggestions in medical education.

In total, there were 32 responses, where surgical training topped the list, focusing on simulated ORs, procedures, and technical skills. Emergency medicine was also common, valued for urgent scenario practice. Other clinical uses included patient consultations, case simulations, and procedures like punctures. XR was seen as helpful for early skills and self-study, though some noted limits in replicating patient communication and empathy. Preclinical interests centered on anatomy, especially 3D visualization, and XR was also suggested for biochemistry, pharmacology, and physiology to illustrate dynamic, abstract concepts.

4 Discussion

Participant demographics mainly included early-year medical students aged 18–25, predominantly female, reflecting enrollment trends and providing mostly preclinical perspectives.

XR terminology awareness was low, with males more familiar; VR and AR were better known than MR, though many struggled to distinguish modalities. Prior exposure was mostly informal (gaming), highlighting the need for hands-on educational experiences to build basic literacy. Despite limited experience, students were open to XR, especially for spatially demanding areas like surgery, radiology, emergency medicine, and anatomy. Seniors preferred clinical ap-

plications, juniors foundational topics, and practical classes and exams were favored, emphasizing XR's experiential strengths. Even skeptical students preferred structured sessions, indicating caution rather than outright rejection. XR's immersive, simulation-based learning was valued for enhancing competence and engagement, though rare disease depiction and scenario repeatability were less emphasized, likely due to curricular limits. Familiarity with XR and institutional support increased appreciation and confidence, while concerns focused on technical reliability, user proficiency, and XR's limitations in replicating authentic patient interactions, particularly communication and teamwork. Females were slightly more optimistic; early-year students showed mixed views; seniors were more cautious. Students prioritized XR for skill-building in high-stakes clinical fields, repeatable scenarios, routine clinical tasks, and preclinical anatomy visualization, but its inability to fully capture empathy and nuanced communication showcases the need for hybrid approaches combining XR with real patient encounters.

In summary, XR holds strong potential for spatial reasoning, procedural training, and immersive simulation, especially in hands-on fields and preclinical 3D visualization. Its interpersonal limitations suggest it should complement, not replace, real-world experience. Thus, early structured exposure can build XR literacy, with applications evolving from theory to clinical practice. Educators should focus on high-value uses, enhance XR's technical and relational capabilities, and embed it within blended learning strategies.

5 Conclusion

This study explored medical students' awareness, experience, and expectations of XR (AR, MR, and VR) at ICBAS. Students were enthusiastic, especially for fields needing spatial visualization and procedural practice like anatomy, surgery, and emergency medicine. However, many struggled to distinguish XR modalities, highlighting a need for basic XR literacy. While immersive learning benefits were clear, concerns about replicating authentic interpersonal interactions and teamwork persisted.

Results suggest that XR should complement rather than replace clinical experience. Students' preference for practical formats and the variation in attitudes across academic years highlight the need for flexible, tailored implementation. Overall, a phased approach, starting with early conceptual exposure and progressing toward clinical applications, combined with accessible technology, strong institutional support, and alignment with the curriculum, is crucial to fully reach XR's educational potential.

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