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Original Article

Needs and challenges in implementing a virtual reality-based assisted reproductive technologies training: a mixed methods study

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Abstract

Background & Objective: Virtual Reality (VR)-based simulation is increasingly recognized as a promising educational tool to address limitations in conventional training for Assisted Reproductive Technologies (ART), such as ethical constraints, limited patient availability, and uneven procedural exposure. In Indonesia, access to structured training in Intrauterine Insemination (IUI) and Embryo Transfer (ET) remains limited. This study explores the needs, challenges, and gender-related perspectives surrounding the implementation of VR-based ART training.

Materials & Methods: An exploratory sequential mixed-methods design was applied. The qualitative phase used two Focus Group Discussions (FGDs) with 15 obstetricians and gynecologists and residents. Findings from the FGDs phase informed the development of a structured questionnaire used in the quantitative phase. The quantitative phase involved an online survey of 100 obstetrics and gynecology doctors and residents. Quantitative data were analyzed using descriptive statistics, while qualitative data were examined using thematic analysis.

Results: Two themes and six sub-themes emerged from the qualitative data: (1) needs toward VR-based ART training, and (2) challenges in VR-based ART training. Quantitatively, over 80% of respondents had no prior VR training experience, although most expressed positive attitudes toward VR as a supplemental educational tool. Gender differences were identified, with male respondents reporting greater confidence in VR's practicality, interactivity, and ease of use, while female respondents more often expressed neutral or cautious agreement.

Conclusion: VR-based ART training holds significant potential to strengthen IUI and ET training in Indonesia, particularly by providing safe, standardized, and repeatable practice opportunities. However, successful implementation requires culturally sensitive planning, investment in infrastructure, gender-responsive design, and regulatory support. Addressing identified challenges early will be key to scalable and sustainable VR integration into medical education.Despite favorable attitudes toward palliative care, the lack of knowledge, particularly in conceptual and psychological domains, should be addressed. The findings highlight the necessity of palliative care training in internal medicine residency programs.

Keywords: education, medical; embryo transfer; insemination, artificial; reproductive techniques, assisted; virtual reality

Introduction

The demand for Assisted Reproductive Technologies (ART), particularly Embryo Transfer (ET) and Intrauterine Insemination (IUI), has risen over the years. According to the World Health Organisation's Collaborative Report on ART, 2,683,677 cycles resulted in 675,134 babies in 2015, and 3,100,448 cycles resulted in 723,026 babies in 2016 [1]. In Indonesia, Wiweko et al. reported that 69,569 ART cycles were performed over the past decade across 41 fertility clinics [2]. These figures highlight the high demand for ART both nationally and globally.

Despite growing international demand and advances in ART, substantial disparities persist across countries in the number of ART births. Variability in operator skill has been shown to be a significant contributor to differences in pregnancy rates, even within the same clinical setting and when using similar protocols [3, 4]. To encourage competency in ART, educational institutions have created various fellowship programs. Most programs need 2 years of training, including practical experience in procedures such as IUI and ET [5]. However, previous studies have shown significant discrepancies in ART training quality, revealing limited access to ET exercises for fellows [6, 7]. Also, more than 40% of third-year fellows have performed fewer than ten transfers during three years of subspecialty training. The high cost and risk of failure make attending physician involvement in embryo transfer necessary, as a result reducing fellows' hands-on exposure in ART practice [7]. In Indonesia, ART training is combined with obstetrics and gynaecology residency training. Similar to fellowship programs worldwide, the educational process relies heavily on conventional methods, such as live patient cases and biological models. While these modalities offer some measure of clinical practice, they are limited by ethical concerns, high costs, and the restricted availability of practice sessions, which tend to reduce the intensity and frequency of practice opportunities [8].

Also, reliance on direct patient contact carries inherent risks, including procedural errors and patient discomfort, especially during sensitive procedures like ET [9]. The imbalance between ART requests and the number of residents also limits live practice.

Each year, Indonesian residency programs typically have 50 to 100 residents, a number that goes beyond the annual ART request. To provide adequate ART training for obstetric residents, Virtual Reality (VR) simulation is now thought to be a promising medium for medical training, as it enables the replication of real-life clinical situations without risking patients [10]. In medical education, VR enables students to practice procedures repeatedly, improve their skills, and get greater confidence in a risk-free, controlled environment [11]. Evidence shows that VR-based training is suitable for precision-dependent procedures such as ET, where slight variations in technique can significantly affect outcomes [12]. For instance, high-fidelity VR simulators, such as the American Society for Reproductive Medicine Embryo Transfer Simulator, have been shown to enhance technical proficiency and confidence among trainees, regardless of experience level [13]. Also, previous studies have noted that user characteristics, especially gender, affect users' acceptance [14]. Despite the growing global evidence supporting the effectiveness of VR-based simulation in ART in developed countries, no empirical studies to date have examined the needs, feasibility, and acceptability of VR-based ART training within the Indonesian context. Indonesia presents unique socio-cultural and infrastructural challenges that may substantially affect VR implementation, including unequal distribution of ART services, variability in institutional resources across regions, and limited access to advanced simulation facilities. Furthermore, medical training in Indonesia remains predominantly apprenticeship-based, with medico-legal concerns and cultural expectations regarding patient involvement in training.

Given the increasing demand for ART services in Indonesia and the persistent limitations in hands-on training for ART, there is an urgent need for innovative, ethical, and scalable training solutions. While VR-based simulation has been shown to improve procedural competence in high-income settings, its applicability cannot be assumed in Indonesia due to distinct socio-cultural norms, infrastructure differences, and potential variations in technology acceptance. Investigation of these is necessary for the development of customised solutions to meet the individual needs of Indonesian residency programs.

This research will further clarify how best to combine VR-based ART training into existing residency programs to make it accessible and sustainable in resource-constrained settings. To bridge this knowledge gap, this study aims to find out the needs and challenges associated with implementing a virtual reality-based simulation for assisted reproductive technologies training in Indonesia, by considering gender as a distinguishing factor.

Materials & Methods

Design and setting(s)

This study used an exploratory mixed-methods design, collecting both qualitative and quantitative data. Cresswell et al. [15] suggested that this design is appropriate when existing instruments are insufficient or unavailable, and when initial qualitative exploration is required to identify key constructs prior to quantitative measurement. When our study was run, no previously validated questionnaire was available that adequately addressed VR-based ART training within the Indonesian educational and sociocultural context, necessitating initial qualitative exploration. Accordingly, Focus Group Discussions (FGDs), followed by an online survey, were carried out from July to September 2024. The qualitative phase aimed to identify the potential problem in VR-based ART training and guide questionnaire design, while the quantitative phase collected larger data.

The study was set up in Indonesia, involving participants from multiple clinical and educational settings, including tertiary and secondary referral hospital doctors, fertility clinic doctors, and obstetrics and gynaecology residents. Data collection took place between July and September 2024. The qualitative phase was conducted through online FGDs to accommodate geographically dispersed participants, while the quantitative phase used an online survey distributed nationally to practicing gynecologists and residents.

Participants and sampling

Participants for the qualitative phase were selected using purposive sampling, which is appropriate for exploratory qualitative research aimed at capturing diverse perspectives. Gynaecologists and residents were intentionally recruited to represent variation in gender, level of training (consultant vs resident), clinical experience, and institutional background. Eligibility criteria included having current clinical practice or residency training in Indonesia and willingness to provide informed consent. Individuals who declined participation were excluded. A total of 15 participants were recruited and assigned to two FGDs, which was thought to be sufficient to achieve thematic saturation.

For the quantitative phase, participants were recruited using convenience sampling through a nationwide online survey distributed to practicing gynaecologists and residents in Indonesia. Inclusion criteria were identical to those of the qualitative phase. Responses with incomplete data were excluded from analysis. A total of 100 respondents completed the survey and were included in the final quantitative analysis.

Tools/Instruments

During *the qualitative phase,* a guide for FGDs was created prior to data collection. A total of 11 questions on respondents' perception towards VR-based ART training were listed for the data collection (**Supplement 1**). To ensure that the respondents' perception could be explored fully, a pilot data collection with all authors was run and followed by reflection of the process. The FGD questions were shown in the supplementary files. After the discussion was complete, experts were asked to evaluate and provide feedback to a self-developed questionnaire draft. The moderator led the discussion and asked respondents for suggestions for each question. This approach was chosen to maintain feasibility and methodological rigor within the study timeframe, as expert review was constrained by competing clinical and academic responsibilities.

In *the quantitative phase,* this study used an online survey consisting of three sections: demographic characteristics, experience with IUI and ET training, and perceptions of general VR learning and VR-based ART training. The questionnaire development process was guided by a literature review and adjusted with the qualitative phase's results. Identified findings related to needs and challenges of VR-based ART training were translated into measurable items to ensure contextual relevance and content validity (**Table 1**). Section A of the survey covered demographic characteristics. Section B, 'Perspective toward VR Learning', comprising seven questions, was designed to assess the perspective of the respondents on the overall effectiveness of VR learning. Section C 'VR-based Training for ART', comprising 17 questions, investigated the respondents' opinion on the use of VR-based training in ART.

Section C was given only to respondents who expressed interest in VR after completing Section B. A 5-point Likert scale was used: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree. The questionnaire's reliability and validity were assessed before data collection. Also, a pilot study involving 30 respondents was carried out to find out the validity and reliability of the instrument [17]. A correlation coefficient of 0.361 or higher was found for all items. Cronbach's alpha values were 0.908 for 'Perspective toward VR Learning' and 0.959 for 'VR-based Training for ART.'

Table 1. Mapping of qualitative themes and subthemes to questionnaire items

Qualitative theme	Subtheme	Conceptual focus from qualitative phase	Corresponding questionnaire items
Needs toward VR-based ART training	High urgency in ART training	Describes factors that increase the needs of VR ART development in medical education (e.g., limited hands-on exposure, ethical constraints in live patient training, high procedural pressure during IUI and ET).	1. VR can enhance the understanding of IUI and ET procedures. 2. VR is effective at simulating real-life experiences during IUI and ET procedures. 3. VR provides hands-on training opportunities for professional skills in IUI and ET. 4. VR can help minimise errors in IUI and embryo transfer procedures in real-world practice. 5. VR training can create a safe environment for practising IUI and embryo transfer.
	Accelerating skills acquisition	Describes VR benefit in accelerating user's (student) learning and ART skill acquisition process (e.g., early procedural exposure, repetitive practice, confidence building, and faster skill mastery before patient-based training).	1. VR is effective as a learning tool for training professionals in obstetrics and gynaecology, particularly for IUI and ET. 2. VR can reduce the learning time needed to acquire IUI and embryo transfer skills. 3. The use of VR can increase confidence in performing IUI and embryo transfer. 4. VR can enhance the professional learning experience related to IUI and ET.
Challenge and future direction	Challenges in VR-based ART Training	Describes user's suggestion for the future features of VR-based ART training (e.g., expectations regarding scalability, feedback mechanisms, curriculum integration, and long-term adoption).	1. VR can provide immediate feedback during IUI and embryo transfer training. 2. In the future, VR-based training will become the standard for IUI and embryo transfer. 3. The use of VR for IUI and embryo transfer training can be standardised across all educational institutions in Indonesia. 4. VR-based training requires less strict supervision compared to traditional training. 5. VR training can be easily integrated into current medical education.
	Pre-development phase	Describes challenges that need to be addressed before the development begins (e.g., user readiness, digital literacy, perceived usefulness, and willingness to adopt VR technology).	1. Using and interacting with VR simulations is easy. 2. I'm interested in integrating VR technology into obstetrics and gynaecology education. 3. The use of VR is worth recommending to colleagues or students for IUI and ET learning.
	Development phase	Describes challenges that need to be addressed during the development (e.g., need for realism, interactivity, usability, anatomical accuracy, and immersive experience).	1. VR can provide a more interactive and effective learning experience than conventional methods. 2. VR can effectively simulate real-life conditions of IUI and embryo transfer. 3. VR can facilitate learning the anatomy involved in IUI and embryo transfer procedures.
	Post-development phase	Describes challenges that need to be addressed after the development is complete (e.g., sustainability, institutional integration, cost justification, supervision, and broader implementation).	1. Doctors would prefer VR-based training over conventional methods for practising IUI and embryo transfer. 2. The cost of developing VR for IUI and embryo transfer will be justified by the training outcomes it produces. 3. The use of VR can facilitate remote learning for IUI and embryo transfer training.

Abbreviations: VR, virtual reality; ART, assisted reproductive technology; IUI, intrauterine insemination; ET, embryo transfer.

Data collection methods

In the qualitative phase, due to a tight schedule, only two FGDs were conducted in this study, which was thought to be the minimum required to reach saturation [18]. A total of 15 respondents with diverse expertise and training levels were invited to participate in the interviews. The FGDs were run via an online meeting platform with a duration of 60-90 minutes. A team member took the role of moderator, while two other members served as the co-moderator and notetaker. In the quantitative phase, the online survey was distributed to 100 Indonesian obstetrician doctors and residents using an online platform. There was an incentive of seven dollars (USD) upon completion of the study. The respondents were assured that the data obtained would be used solely for research purposes and would be made available only to the research team. All responses were made anonymous to reduce possible bias. Before beginning the survey, the study's purposes were presented, followed by an informed consent section. If the respondent disagreed, progress to the next section would be stopped.

Data analysis

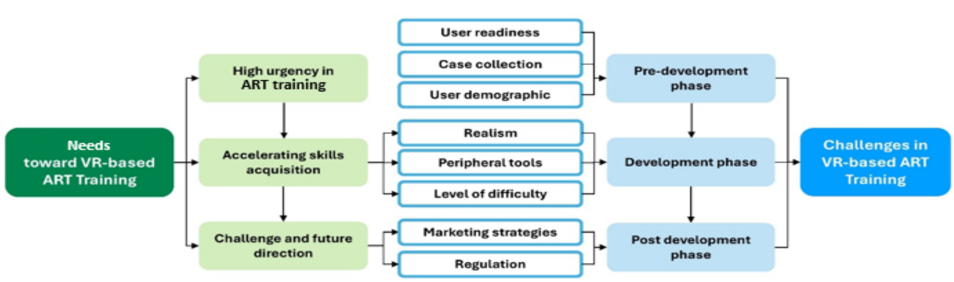
In the qualitative phase, the data were analysed using thematic analysis. The FGDs were video recorded and transcribed verbatim. The Steps for Coding and Theorisation (SCAT) [19] were used to carry out a thematic analysis, identifying sub-themes and overall themes related to respondents' opinions on VR-based ART training.

The initial analysis was run separately by two authors on the first transcript. The results were then discussed collaboratively to reach a consensus. If consensus could not be reached, a third member was consulted to resolve any discrepancies. Once the sub-themes and themes were established, the remaining transcripts were analysed by the rest of the team.

Throughout this process, a complete and rigorous data analysis was ensured. In this study, we employed multiple strategies during our study to ensure trustworthiness. We enhanced the credibility of our study through rapport and trust building, iterative data analysis, and member checking to clarify misinformation or distortion and confirm interpretations. We maintained a clear audit trail documenting methodological decisions, data collection procedures, and analytic steps to enable transparency and consistency, thus supporting dependability of this study. To address confirmability, we wrote reflective notes regularly and discussed data, codes, and interpretations with senior researchers. These approaches aimed to reduce researcher bias and ensure that findings were grounded in participants' accounts. Lastly, we ensured transferability by providing descriptions of the research context and participants, allowing readers to assess the applicability of the findings to similar settings. In the quantitative phase, the IBM Corporation SPSS version 24.0 (Armonk, New York, United States) was used for data management and statistical analysis. Descriptive statistics were used to summarise the data, with frequencies and percentages reported for categorical variables and means with standard deviations or medians with interquartile ranges reported for continuous variables, depending on data distribution. Comparative analyses for categorical variables were carried out using the chi-square test, as this test is appropriate for examining associations between independent categorical variables. For continuous variables, the independent t-test was applied when the data met the assumption of normal distribution, while the Mann–Whitney U test was used for non-normally distributed data due to its non-parametric nature. Statistical significance was set at $p < 0.05$.

Results

A total of 15 respondents participated in our FGDs and 100 respondents completed the online survey. Qualitative phase of This study's results show that the development of VR in IUI and ET training is linked to several interconnected aspects, including technical and ethical issues related to VR, which affect users' and decision-makers' perspectives and the future directions of VR development and implementation. Two themes and six sub-themes emerged during the analysis. An elaboration on each theme is provided, accompanied by representative quotes. The connections between themes and subthemes are shown in **Figure 1**.



Needs for VR-based ART training	
High urgency in ART training	Describes factors that increase the needs of VR ART development in medical education
Accelerating skills acquisition	Describes VR benefit in accelerating user's (student) learning and ART skill acquisition process
Challenge and future direction	Describes user's suggestion for the future features of VR-based ART training

Challenges in VR-based ART Traininig	
Pre-development phase	Describes challenges that need to be addressed before the development begin
Development phase	Describes challenges that need to be addressed during the development
Post-development phase	Describes challenges that need to be addressed after the development complete

Figure 1. Extracted themes and subthemes. The figure describes two overarching themes and their interrelated subthemes derived from qualitative analysis. It demonstrates how user needs, technical requirements, and regulatory considerations collectively shape the feasibility and implementation of VR-based ART training.

Theme 1: Needs toward VR-based ART training

The potential needs of VR in ART training were acknowledged in this study. Respondents mentioned the high urgency in updating ART training, the need to speed up skill acquisition, and address future direction for VR-based ART training development.

High urgency in ART training

Respondents believed that the need to develop VR for ART training had already increased due to a shift in perception of VR as an essential educational tool, given its potential to replace actual patients for training. Furthermore, IVF live training can be very stressful for operators due to their moral responsibility, which creates fear and pressure during embryo transfer.

> *"I believe the need for VR development has progressed from 'should' to 'must' stage. It would be much better if we could use VR to replace real patients for IUI and ET training."* (**Participant A, female**)

> *"In IVF procedures, it's very stressful for the operator because what they transfer is more valuable than diamonds, so there is a significant moral burden on those performing embryo transfer. They are dealing with the patients' hopes, and the material involved in IUI and embryo transfer is also very costly. Sometimes the operators become fearful because of that."* (**Participant MN, male**)

Also, VR training needs to be combined into formal education, aligning with the specific learning objectives for different levels of medical trainees.

> *"They probably need to pass the VR first. Also, VR can be integrated into the curriculum."* (**Participant BK, male**)

The use of VR in ART training is best targeted for residents with no experience in performing ART. Other potential users of VR include nurses who help during procedures. VR-based training helps them better prepare for actual procedures.

> *"From what I see, this will be very helpful for those who have never performed IUI and ET before."* (**Participant MM, female**)

> *"It's not only us as operators who need training, but also the nurses who help us with ultrasound, especially during the embryo transfer."* (**Participant CAS, female**)

Accelerating skills acquisition

The use of VR-based training tools for IUI and ET procedures will improve skill acquisition by introducing residents to the procedures before hands-on practice with actual patients. Learning through digital simulation offers an effective way to prepare residents for the challenges of managing actual patients.

> *"VR simulation will help skill acquisition. During training, residents can use VR to practice procedures on a digital patient before performing them on a real patient."* (**Participant BW, male**)

> *"The use of VR should be able to help further obstetrics and gynaecology specialists to strengthen their mastery of the techniques and knowledge related to IUI and embryo transfer."* (**Participant AS, female**)

Challenge and future direction

Our respondent believed that in the future, the development of VR will involve adding new cases and introducing haptic feedback, thereby improving its immersion by adding a sense of touch.

Advances in haptic technology would address the limitations of current VR systems, such as the inability to replicate tactile sensations, which are essential for IUI and ET procedures.

> *"The advantage of a computer-based application is that it can always be further developed in the future. If you want to add difficulty levels or vary the cases, it can definitely be done."* (**Participant AKH, male**)

> *"The next big thing in VR advancement is the development of haptics. The initiative to set up the haptic technology is interesting, as the immersiveness of this tool can simulate the sense of touch, rather than relying solely on our imagination."* (**Participant WI, male**)

Theme 2: Challenges in VR-based ART training

Although VR potentially benefits IUI and ET training, several challenges must be addressed first. Challenges can be identified from the beginning of VR development, during the development process, and after the VR is ready to use. To ensure users get benefits from VR, these challenges must be addressed thoughtfully.

Pre-development phase

Before the development begins, the VR user's demographics and readiness need to be further explored. The older generation of doctors often reported inconvenience during VR activities, which makes this learning method ineffective for this age group.

> *"User demographics also play a role in determining effectiveness, as VR is less popular among*

> *individuals aged 40 and above due to perceived inconvenience."* (**Participant WI, male**)

Moreover, this study revealed the possible challenge of getting ethical permission from the patient during the case collection phases. The team should do the selection process strictly and include only cases with no potential ethical issues in the future.

> *"If we get permission from the patient, it does not violate the code of ethics. However, not all patients are willing to grant permission."* (**Participant A, female**)

Another issue that needs to be addressed before VR development is the readiness of the infrastructure. The VR hardware (e.g., a head-mounted device) for VR training must be available. This study respondent also emphasised the need to ensure that human resources to manage VR in each institution are available. The inability to provide the technical team could reduce VR's effectiveness and lifetime.

> *"I think we are ready to carry out VR training. However, its implementation depends on the availability of VR devices."* (**Participant MN, male**)

> *"There are several important challenges in distributing VR: Is a VR headset available at the target institution? Who will maintain the VR after purchase? Who will run it? Who will be responsible for repairs if the headset is damaged? Where will VR be used during learning activities?"* (**Participant WI, male**)

Besides the infrastructure, low digital literacy among users and decision-makers hinders the use of VR.

> *"Technological literacy can affect the level of VR usage in institutions."* (**Participant WI, male**)

Development phase

During VR development, several factors need to be considered, such as similarity to the real settings, feedback sensation, field of view, and difficulty level. Our respondents highlighted realism several times. They believed that high realism, with a wide variety of case difficulties, would determine the effectiveness of the VR approach. The use of peripheral tools, such as a catheter, could help achieve high immersion during training.

> *"VR can be better adapted to the real world, with more advanced stages, and can resemble real patients more closely."* (**Participant AS, female**)

> *"What matters in VR is that the application and the device resemble real conditions in the field (the clinical setting). If the device is made to feel like a catheter that mimics reality, it could be a good solution."* (**Participant MN, male**)

Feedback on sensation during the procedure must be combined into the training. This creates a more realistic situation for IUI and ET procedures.

> *"For VR in IUI or ET, we need to be able to feel the feedback sensation when performing the embryo transfer or insemination."* (**Participant MN, male**)

A clear, wide field of view is also required during training. The obstacle from the user's perspective must be removed to improve the training experience.

> *"The problem with carrying out the procedure is the field of view during observation. Starting with the technical aspect of the patient's position, the ultrasound field of view is sometimes obstructed. If there is something that can improve this, it would be much better."* (**Participant AS, female**)

Lastly, the difficulty levels for beginner and experienced users should be added to the VR module. The difference can be seen in the technique required or in the complexity of the patient's anatomy.

> *"The difficulty level needs to be varied. So, as I mentioned earlier, for beginners, what matters is being able to perform the insertion for embryo transfer and intrauterine insemination, because the main technique is how to insert the catheter."* (**Participant A, female**)

> *"We can present simulations of clinical obstacles, such as polyps or cervical shapes that are hyperanteflexed, retroflexed, or tilted with the bladder, to adjust the distance that must be navigated between the anus, uterus, and the catheter tip. This is highly beneficial for learning clinical procedures."* (**Participant MN, male**)

Post-development phase

After development is complete, the next challenge is the lack of government regulations for VR. Also, there are significant data privacy risks due to VR's ability to collect specific user data.

Although there is an initiative to set up a VR association, our respondents believe it is still in its early stages and not yet well-established.

> *"Currently, there are no regulations related to VR in Indonesia. Unfortunately, in Indonesia, VR development has not yet reached a critical point for economic turnover, resulting in minimal government attention to creating regulations.*
> *In contrast, some overseas countries have some VR-related regulations, particularly addressing data privacy concerns. VR systems can collect highly detailed analytical data, such as head movements,*

hand gestures, facial expressions, and eye movements, making data privacy regulations important." (**Participant WI, male**)

Competition in VR development in Indonesia remains very low due to marketing issues. Creating a market by addressing user needs or by combining VR into workshops can be a potential solution to the problem, as proven by a respondent's previous experience.

"Developers are not yet interested in developing VR in Indonesia because marketing it is difficult." (**Participant WI, male**)

"When we developed VR, we also created training on how to use it, and the results were quite good. We were able to experience a realistic simulation without involving actual patients." (**Participant A, female**)

In quantitative phase of the study a total of 100 respondents completed the online survey, with an equal male-to-female ratio. There was a significant difference across age groups ($p = 0.007$): the majority of male respondents were in the 40-49 years age group (18%), whereas among female respondents, it was the 30-39 years age group (25%). The demographic characteristics of the respondents are shown in **Table 2**.

Table 2. Respondents' demographic characteristics and VR experience

Category	Male (n = 50)		Female (n = 50)		Sig.
	n	(%)	n	(%)	
Age (median, min-max)	38	(27-62)	30	(25-54)	$U = 625.0$ $p = 0.001$
Age category (years)					
20-29	10	(20.00)	17	(34.00)	$X^2 = 7.35$ $p = 0.061$
30-39	16	(32.00)	25	(50.00)	
40-49	18	(36.00)	7	(14.00)	
≥ 50	6	(12.00)	1	(2.00)	
Workplace type					
Tertiary referral hospital	20	(40.00)	14	(28.00)	$X^2 = 9.23$ $p = 0.100$
Secondary referral hospital	13	(26.00)	6	(12.00)	
Primary referral hospital	2	(4.00)	6	(12.00)	
Primary hospital	1	(2.00)	1	(2.00)	
Clinic	1	(2.00)	0	(0.00)	
Resident of OBGYN (unemployed)	13	(26.00)	23	(46.00)	
Experienced					
VR-based knowledge training					
Never	40	(80.00)	46	(92.00)	$X^2 = 5.48$ $p = 0.241$
1 Time	7	(14.00)	2	(4.00)	
2-3 Times	2	(4.00)	1	(2.00)	
4-5 Times	1	(2.00)	0	(0.00)	
> 5 times	0	(0.00)	1	(2.00)	
Experienced in VR-based skill training					
Never	36	(72.00)	47	(94.00)	$X^2 = 8.57$ $p = 0.014$
1-2 Time	9	(18.00)	2	(4.00)	
> 2 Times	5	(10.00)	1	(2.00)	
Comfort levels when using VR					
Very uncomfortable	1	(2.00)	0	(0.00)	$X^2 = 1.79$ $p = 0.774$
Uncomfortable	1	(2.00)	2	(4.00)	
Neutral	20	(40.00)	21	(42.00)	
Comfortable	20	(40.00)	19	(38.00)	
Very comfortable	8	(16.00)	8	(16.00)	

Note: Mann-Whitney U test was used to compare age between groups. Chi-square test was used for categorical variables.
Abbreviations: n, number of participants; VR, virtual reality; OBGYN, obstetrics and gynecology; Sig., statistical significance; p, probability-value; X^2, Chi-square test; U, Mann-Whitney U test.

Male respondents were mainly working in tertiary referral hospitals (20%), whereas the majority of female respondents were doing obstetrics and gynaecology residency training (23%). There was no significant difference in respondents' workplace types. For the VR experience, although the majority of responses from both groups reported no use of VR for skills or knowledge training, the proportion of male respondents with experience in VR-based skills training was significantly higher than that of female respondents (p = 0.014). Comfort levels when using VR varied, with 20% males and 19% females reporting being ‘comfortable’ while 8% in both groups responded ‘Very comfortable’. However, a small number of respondents felt ‘uncomfortable’ and ‘very uncomfortable’, highlighting that some obstacles may stem from unfamiliarity or perceived complexity of the technology. No significant difference in comfort level was found when using VR (**Table 2**).

Although both genders showed positive perception toward VR-based ART training, in several aspects respondents still showed statistically significant differences (**Table 3**). Male and female respondents showed a significant difference regarding the assumption that VR improves understanding of IUI and ET, with more females expressing neutral agreement (p = 0.015). Moreover, regarding VR’s ability to simulate real-life experiences, male respondents showed a more positive perspective than their counterparts (p = 0.004). However, for ‘VR provides hands-on training opportunities for professional skills in IUI and ET’, male respondents showed only a neutral perspective, whereas female respondents showed positive agreement. Ease of use was also rated positively, with males more likely to choose the highest Likert scores (p = 0.017). Finally, the perception that VR improves professional learning in IUI and ET was widely supported, with male respondents reporting a significantly higher score (p = 0.043).

Table 3. Perspectives toward VR-based learning regarding IUI and ET procedures

Statement	Gender	n (%)					Sig.
		1	2	3	4	5	
VR can enhance the understanding of IUI and ET procedures.	M	1 (2.0)	1 (2.0)	8 (16.0)	25 (50.0)	15 (30.0)	X^2 = 12.12
	F	2 (4.0)	1 (2.0)	13 (26.0)	32 (64.0)	2 (4.0)	p = 0.016
VR is effective as a learning tool for training professionals in obstetrics and gynaecology, particularly for IUI and ET.	M	1 (2.0)	3 (6.0)	6 (12.0)	26 (52.0)	14 (28.0)	X^2 = 6.88
	F	1 (2.0)	1 (2.0)	9 (18.0)	35 (70.0)	4 (8.0)	p = 0.142
The use of VR is worth recommending to colleagues or students for IUI and ET learning.	M	0 (0.0)	2 (4.0)	12 (24.0)	21 (42.0)	15 (30.0)	X^2 = 9.48
	F	1 (2.0)	1 (2.0)	18 (36.0)	26 (52.0)	4 (8.0)	p = 0.051
VR is effective at simulating real-life experiences during IUI and ET procedures.	M	0 (0.0)	1 (2.0)	16 (32.0)	18 (36.0)	15 (30.0)	X^2 = 13.28
	F	1 (2.0)	1 (2.0)	21 (42.0)	26 (52.0)	1 (2.0)	p = 0.010
VR provides hands-on training opportunities for professional skills in IUI and ET.	M	0 (0.0)	0 (0.0)	12 (24.0)	24 (48.0)	14 (28.0)	X^2 = 24.50
	F	1 (2.0)	1 (2.0)	1 (2.0)	13 (26.0)	34 (68.0)	p < 0.001
Using and interacting with VR simulations is easy.	M	0 (0.0)	2 (4.0)	24 (48.0)	14 (28.0)	10 (20.0)	X^2 = 11.96
	F	1 (2.0)	2 (4.0)	28 (56.0)	19 (38.0)	0 (0.0)	p = 0.018
VR can enhance the professional learning experience related to IUI and ET.	M	0 (0.0)	2 (4.0)	15 (30.0)	21 (42.0)	12 (24.0)	X^2 = 10.00
	F	1 (2.0)	1 (2.0)	21 (42.0)	25 (50.0)	2 (4.0)	p = 0.040

Note: Chi-square test was used to compare responses between male and female groups.
Abbreviations: VR, virtual reality; IUI, intrauterine insemination; ET, embryo transfer; M, male; F, female; X^2, Chi-square test; Sig., statistical significance; p, probability-value.

Both male and female respondents agree that VR-based ART training has potential to be used in medical education (**Table 4**). Interest in combining VR into ART training was equal between the two groups, with no significant difference (p = 0.970). However, male respondents were significantly more likely to agree that VR offers a more interactive and practical learning experience than conventional methods (p = 0.003). While both genders agreed VR can make easier learning the anatomy involved in IUI and embryo transfer, this item did not show a statistically significant difference (p = 0.296). Moreover, both groups also endorsed VR’s ability to simulate real-life conditions, though there was no significant difference (p = 0.153). An insignificant difference was also found in the item ‘The use of VR can make easier remote learning for IUI and embryo transfer training’ (p = 0.078).

Significant differences between male and female respondents (p<0.005) were observed on the remaining items in this table, with male respondents showing greater positive agreement toward VR use in ART training.

Table 4. Respondents' perceptions of VR-based ART training

Statement	Gender	n (%) 1	2	3	4	5	Sig.
I'm interested in integrating VR technology into obstetrics and gynaecology education.	M	0 (0.0)	0 (0.0)	26 (59.1)	18 (40.9)	0 (0.0)	X² = 0.00
	F	0 (0.0)	0 (0.0)	27 (58.7)	19 (41.3)	0 (0.0)	p = 0.970
VR can provide a more interactive and effective learning experience than conventional methods.	M	0 (0.0)	2 (4.5)	6 (13.6)	21 (47.7)	15 (34.1)	X² = 14.04
	F	0 (0.0)	1 (2.2)	20 (43.5)	21 (45.7)	4 (8.7)	p = 0.007
VR can facilitate learning the anatomy involved in IUI and embryo transfer procedures.	M	0 (0.0)	1 (2.3)	5 (11.4)	21 (47.7)	17 (38.6)	X² = 4.86
	F	0 (0.0)	1 (2.2)	12 (26.1)	21 (45.7)	12 (26.1)	p = 0.302
VR can reduce the learning time needed to acquire IUI and embryo transfer skills.	M	0 (0.0)	3 (6.8)	7 (15.9)	20 (45.5)	14 (31.8)	X² = 16.86
	F	0 (0.0)	3 (6.5)	16 (34.8)	26 (56.5)	1 (2.2)	p = 0.002
VR can effectively simulate real-life conditions of IUI and embryo transfer.	M	0 (0.0)	1 (2.3)	9 (20.5)	23 (52.3)	11 (25.0)	X² = 6.96
	F	0 (0.0)	1 (2.2)	16 (34.8)	25 (54.3)	4 (8.7)	p = 0.138
Doctors would prefer VR-based training over conventional methods for practising IUI and embryo transfer.	M	0 (0.0)	4 (9.1)	10 (22.7)	21 (47.7)	9 (20.5)	X² = 9.76
	F	0 (0.0)	2 (4.3)	24 (52.2)	17 (37.0)	3 (6.5)	p = 0.044
The cost of developing VR for IUI and embryo transfer will be justified by the training outcomes it produces.	M	0 (0.0)	3 (6.8)	14 (31.8)	15 (34.1)	12 (27.3)	X² = 9.24
	F	0 (0.0)	1 (2.2)	24 (52.2)	18 (39.1)	3 (6.5)	p = 0.055
VR can help minimise errors in IUI and embryo transfer procedures in real-world practice.	M	0 (0.0)	0 (0.0)	13 (29.5)	21 (47.7)	10 (22.7)	X² = 8.68
	F	0 (0.0)	2 (4.3)	23 (50.0)	18 (39.1)	3 (6.5)	p = 0.034
VR training can be easily integrated into current medical education.	M	0 (0.0)	1 (2.3)	8 (18.2)	25 (56.8)	10 (22.7)	X² = 9.76
	F	0 (0.0)	1 (2.2)	19 (41.3)	24 (52.2)	2 (4.3)	p = 0.044
VR-based training requires less strict supervision compared to traditional training.	M	2 (4.5)	11 (25.0)	10 (22.7)	14 (31.8)	7 (15.9)	X² = 14.04
	F	0 (0.0)	17 (37.0)	21 (45.7)	8 (17.4)	0 (0.0)	p = 0.007
In the future, VR-based training will become the standard for IUI and embryo transfer.	M	0 (0.0)	1 (2.3)	12 (27.3)	22 (50.0)	9 (20.5)	X² = 11.04
	F	0 (0.0)	1 (2.2)	25 (54.3)	19 (41.3)	1 (2.2)	p = 0.026
VR training can create a safe environment for practising IUI and embryo transfer.	M	0 (0.0)	1 (2.3)	8 (18.2)	23 (52.3)	12 (27.3)	X² = 10.42
	F	0 (0.0)	1 (2.2)	20 (43.5)	22 (47.8)	3 (6.5)	p = 0.034
The use of VR can increase confidence in performing IUI and embryo transfer.	M	0 (0.0)	0 (0.0)	9 (20.5)	24 (54.5)	11 (25.0)	X² = 9.24
	F	0 (0.0)	1 (2.2)	17 (37.0)	26 (56.5)	2 (4.3)	p = 0.055
The use of VR is effective as a supplement to hands-on training for IUI and embryo transfer.	M	0 (0.0)	2 (4.5)	7 (15.9)	25 (56.8)	10 (22.7)	X² = 8.68
	F	0 (0.0)	1 (2.2)	18 (39.1)	24 (52.2)	3 (6.5)	p = 0.070
The use of VR for IUI and embryo transfer training can be standardised across all educational institutions in Indonesia.	M	0 (0.0)	2 (4.5)	8 (18.2)	23 (52.3)	11 (25.0)	X² = 12.24
	F	0 (0.0)	1 (2.2)	24 (52.2)	19 (41.3)	2 (4.3)	p = 0.016
VR can provide immediate feedback during IUI and embryo transfer training.	M	0 (0.0)	0 (0.0)	9 (20.5)	24 (54.5)	11 (25.0)	X² = 8.68
	F	0 (0.0)	1 (2.2)	18 (39.1)	25 (54.3)	2 (4.3)	p = 0.070
The use of VR can facilitate remote learning for IUI and embryo transfer training.	M	0 (0.0)	0 (0.0)	8 (18.2)	23 (52.3)	13 (29.5)	X² = 5.76
	F	0 (0.0)	1 (2.2)	18 (39.1)	20 (43.5)	7 (15.2)	p = 0.124

Note: Chi-square test was used to compare perceptions between male and female groups.
Abbreviations: VR, virtual reality; ART, assisted reproductive technology; IUI, intrauterine insemination; ET, embryo transfer; M, male; F, female; X², Chi-square test; Sig., statistical significance; p, probability-value.

Discussion

The qualitative findings revealed a strong need for VR-based simulation to support IUI and ET training, particularly to speed up skills acquisition, reduce procedural anxiety, and address ethical constraints related to live patient training. Key challenges identified included user readiness, infrastructural limitations, the need for high procedural realism, and the absence of clear regulatory frameworks. Quantitatively, although most respondents had no prior experience with VR training, the majority expressed positive acceptance of VR as a supplementary educational tool. Notably, gender-related differences were observed, with male respondents reporting higher confidence in VR practicality, interactivity, and ease of use, while female respondents more frequently expressed neutral or cautious agreement. VR-based ART training has shown its potential to disrupt medical education through immersive, interactive simulations. Several published studies highlighted VR's ability to make easier learning, especially in medical skill training. However, several aspects, such as user demographics, perspectives, and preparedness, need to be addressed before developing and carrying out VR [20, 21]. A careful needs analysis would serve as a basis and rationalisation for developing

VR-based ART training. This study revealed the need for VR-based ART training among obstetricians and gynaecologists and residents. Findings also suggested challenges in developing VR-based ART training, underscoring the need to address them to maximise VR's benefits. The findings of this study strongly support the suggestion that VR can improve training outcomes. Respondents expressed overwhelmingly positive attitudes toward VR, with male respondents showing greater agreement. These results align with global studies demonstrating VR's capacity to replicate real-world clinical scenarios while ensuring patient safety [22–24]. For example, the ASRM embryo transfer simulator has improved confidence, technical skill, and comfort levels among trainees [24, 25]. Additionally, VR offers the flexibility to simulate a variety of complex anatomical and procedural challenges, allowing trainees to develop problem-solving skills and procedural adaptability [23, 26, 27]. The ability to receive immediate feedback and engage in repetitive practice enhances skill retention. It reduces the time required to achieve proficiency, strengthening the rationale for using VR in IUI and ET training. In this study, about 40% of respondents believed that VR is easy to use, and the majority also felt it significantly boosts confidence in performing IUI and ET procedures, reaffirming its usability and psychological benefits in training environments [24, 28, 29]. The findings also suggest that VR-based training is particularly well-suited for addressing disparities in access to training across Indonesia. The ability of VR to make easier remote learning, as believed by about 70% of respondents, offers a scalable solution for residency programs in underserved regions. This aligns with global trends demonstrating the feasibility of VR in several countries, where it has been effectively used to train clinicians in other high-stakes procedures [28, 30, 31].

Interestingly, our findings showed gender differences in perceptions of VR training. Male respondents were more likely to rate VR as practical, easy to use, and superior to traditional methods, whereas female respondents were more neutral, emphasising usability and emotional comfort.

The gender-related differences observed in this study may be interpreted through the established framework of technology acceptance and cognitive processing. Immersive VR environments often emphasise spatial navigation, visual-motor coordination, and rapid interaction, which have been shown to align closely with male users. Male respondents in this study reported higher confidence in the practicality and ease of use of VR-based training, which may make easier stronger acceptance. This aligns with recent reports suggesting that gender affects digital tool adoption and immersive learning engagement, potentially due to differences in cognitive and ergonomic preferences [32, 33]. Recognising these distinction is crucial to ensuring that VR systems are inclusively designed, incorporating adaptive interfaces, intuitive navigation, and ergonomic calibration that accommodate diverse user needs and learning styles.

The qualitative phase generated in-depth insights into learners' perceived needs, ethical considerations, and contextual barriers related to VR combination in reproductive training. Respondents expressed strong enthusiasm for VR as a means to reduce patient-related anxiety and improve procedural readiness, particularly among early-stage residents and nurses. These qualitative themes highlight that VR does not merely substitute for hands-on learning but makes easier a psychologically safer and ethically acceptable environment for learners, consistent with findings from recent studies on simulation-based medical education [34, 35].

Combination of VR into reproductive medicine training also aligns with the ethical and cultural sensitivities of Indonesian medical practice. Respondents highlighted the importance of ensuring training methods respect patient privacy and reduce risks associated with live procedures. VR satisfies these ethical requirements by providing a risk-free, patient-independent training environment while allowing trainees to get valuable experience [24, 36]. Moreover, respondents viewed the culturally tailored approach to VR module development, such as simulating common clinical scenarios in Indonesia, favourably. The majority recommended VR as a supplementary tool to improve the current training landscape, reflecting its acceptability among medical professionals.

The high cost of initial preparations was one of the challenges in carrying out VR. Literature from similar resource-limited settings suggests that while initial costs may be high, the long-term benefits of VR (reduced training errors, improved clinical efficiency, and standardised outcomes) justify these investments [25, 36]. Additionally, combining VR into existing educational frameworks may offset costs by increasing training capacity and reducing reliance on live patient interactions. In our study, most respondents agreed that investments in VR would be worthwhile but would need careful resource management.

The qualitative phase provided additional context to these quantitative trends, highlighting practical barriers such as insufficient VR infrastructure, lack of local technical support, and ethical concerns regarding patient data collection for simulation modelling. These issues mirror those reported in other low- and middle-income countries, where digital literacy gaps among educators and inconsistent institutional support slow technology adoption [37]. Thus, carrying out VR in Indonesia requires not only financial planning but also strategic human resource development and institutional readiness assessments.

Medical schools and organisations that plan to invest in VR as an IUI and ET training tool should prepare a grand design that includes a three- to five-year road map, blueprints, and a robust business canvas. Organising methods for disseminating and selling VR products helps institutions generate financial benefits for future development.

A well-planned grand design could reduce the burden of high initial costs and ensure the sustainability of the VR-based ART training.

This study's findings, combined with evidence from international research, underscore the need for a blended training approach. VR should be combined with supervised clinical practice to provide a complete learning experience. For example, structured VR programs, such as the ASRM Embryo Transfer Certificate Course, can serve as models for developing localised training standards [24]. The standardisation of VR-based training across Indonesian institutions, supported by about 60% of respondents, would ensure consistent learning outcomes and equitable access to high-quality education. Strategic working together between stakeholders, including medical institutions, technology developers, and decision-makers, is required to support this initiative. Subsidising VR infrastructure and fostering partnerships can address cost concerns and encourage broader options. As VR technology evolves, the development of advanced features such as haptic feedback and real-time assessments will further improve its utility. This mixed-methods design enabled an exploratory combination, with qualitative findings first used to identify factors underlying VR adoption in ART training, such as procedural anxiety, fear of error, and moral burden during live embryo transfer. These themes informed the development and interpretation of the quantitative survey. While the quantitative results showed overall acceptance of VR-based training, the qualitative phase provided explanatory depth, revealing that acceptance was shaped less by perceived usefulness alone and more by the need for psychological safety in high-stakes procedures. The qualitative findings played a primary role in explaining and contextualizing the quantitative patterns, consistent with an exploratory sequential approach.

The convergence of both data streams strengthens the interpretation that VR acceptance in ART training is not purely determined by perceived usefulness but by procedural errors and moral burden in live embryo transfer affected the eagerness to adopt VR, underscoring the psychological safety dimension as a major facilitator, an aspect less captured in quantitative measures.

A major strength of this study lies in its exploration of perceptions across obstetricians and gynaecologists at different stages of their careers. The variability of our respondents provides a complete understanding of the VR implementation challenges and opportunities in various levels of residency curricula.

Furthermore, combining qualitative and quantitative methodologies enhances the depth of analysis, enabling discussions of feasibility, accessibility, and the potential to standardise VR training. Several limitations of this study should be acknowledged.

First, although the questionnaire showed good content validity through expert review and acceptable internal consistency as indicated by Cronbach's alpha, construct validity was not assessed through exploratory or confirmatory factor analysis.

Consequently, the extent to which the questionnaire items accurately represent the underlying constructs derived from the qualitative phase cannot be fully confirmed, and the quantitative findings should therefore be interpreted with caution. Second, the quantitative phase used convenience sampling and relied on self-reported data from a relatively small sample, which may limit generalisability and introduce response biases such as social desirability bias. In addition, the absence of direct comparisons between VR-based and conventional training outcomes restricts the ability to draw conclusions regarding the relative effectiveness of VR-based ART training. Finally, as this study was carried out within the context of a middle-income country with variable infrastructure and access to simulation technologies, the findings may not be directly transferable to settings with substantially different healthcare systems or technological resources. Future studies should carry out complete psychometric validation, including factor analysis, to confirm the factor structure and construct validity of the instrument prior to its wider application in VR-based ART training research.

Conclusion

VR-based ART training offers a transformative opportunity to address IUI and ET training gaps in Indonesia. Most respondents recognised VR's potential to improve hands-on training opportunities in IUI or ET procedures. However, male respondents showed a more positive perspective toward VR training compared to their counterparts. In addition, this study revealed several challenges before, during, and after the development process.

By aligning with cultural and ethical considerations, VR can complement existing frameworks, providing consistent, accessible training for IUI and ET procedures. These findings suggest that VR-based simulation has strong potential to address persistent gaps in IUI and ET training in Indonesia by offering a safe, standardized, and repeatable learning environment.

Both qualitative and quantitative findings indicate high perceived usefulness of VR, particularly for early-stage trainees, while also revealing important challenges related to infrastructure readiness, user preparedness, ethical considerations, and gender-specific differences in technology acceptance. National-level support is needed to ensure sustainability, including the development of regulatory frameworks addressing ethical use, patient data protection, and standardization of VR-based training in ART.

Ethical considerations

The FKUI-RSCM Research Ethical Committee has approved this study with ethical clearance number KET-814/UN2.F1/ETIK/PPM.00.02/2024. All respondents provided informed consent before participating in the study. The anonymity and confidentiality of all respondents were maintained throughout the research process.

Artificial intelligence utilization for article writing

The authors used Grammarly (Grammarly Inc., San Francisco, CA, USA) to help in improving grammar, spelling, and language clarity throughout the manuscript. The software was not used to create content, analyse data, or draw conclusions. All AI-assisted outputs were critically reviewed and edited by the authors to ensure accuracy and academic integrity.

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Conflict of interest statement

The authors declare no conflicts of interest concerning the authorship and/or publication of this article.

Author contributions

MI and LSA were the first authors to develop the idea, create the concept and research pathway, collect data, and write the manuscripts.

AP, APa, and NS gathered all the data and performed the statistical analysis. AS, MM, AKH, GP, KS, RM, BW, and AS provided the manuscript, proofreading, and additional insights for the discussion. All the authors had approved the manuscript.

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Data availability statement

The datasets analyzed during the current study are not publicly available due to institutional policy but are available from the corresponding author on reasonable request.

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Supplement 1. Focus group discussion question list

Opening Questions

1. How long have you been developing VR technology?
2. How has your experience been in developing VR technology so far?
3. Do you have any memorable experiences during the development process?

Main Questions

4. In your opinion, how is VR technology currently being utilized in Indonesia?
    a. What are the supporting factors for the utilization of VR technology in Indonesia?
    b. What challenges have you encountered in the utilization of VR technology in Indonesia?
5. Based on your experience, in what contexts can VR technology be used?
    a. In which fields is VR technology most suitable to be applied?
    b. Do you think Indonesian society is ready to adopt VR technology?
    c. What preparations are needed for the implementation of VR technology in Indonesia?
6. In your opinion, what are the key elements that make users feel comfortable when using VR technology?
    a. How do these key elements influence the user experience?
    b. Based on your experience, have there been any complaints regarding the use of VR technology?
7. Based on your experience, how is the use of VR technology in the field of Obstetrics and Gynecology, particularly for Intrauterine Insemination (IUI) and Embryo Transfer procedures? Is the use of VR technology appropriate for this field?
    a. In what contexts or situations is VR technology suitable to be applied in this field?
    b. How sustainable is the use of VR technology in this field?
8. In your opinion, what are the benefits and impacts of using VR technology in the field of Obstetrics and Gynecology, particularly for IUI and Embryo Transfer procedures?
9. How is the current development process of VR technology in the field of Obstetrics and Gynecology, particularly for IUI and Embryo Transfer procedures?
    a. What are the supporting factors for the development process of VR technology in the field of Obstetrics and Gynecology, particularly for IUI and Embryo Transfer procedures?
    b. What are the inhibiting factors for the development process of VR technology in the field of Obstetrics and Gynecology, particularly for IUI and Embryo Transfer procedures?

Closing Questions

10. What are your hopes regarding the use of VR technology in general, and specifically in the field of Obstetrics and Gynecology for IUI and Embryo Transfer procedures?
11. Do you have any additional comments?