Asia Pacific Academy of Science Pte. Ltd.

Metaverse 2026, 7(2), 8529.
https://doi.org/10.54517/m8529

Review

Exploring the opportunities of the metaverse in obstetrics and gynecology education

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CITATION

Meng LB, Xue W, Ma JY, Li WJ, Li JX. Exploring the opportunities of the metaverse in obstetrics and gynecology education. Metaverse. 2026; 7(2): 8529. https://doi.org/10.54517/m8529

ARTICLE INFO

Received: 30 January 2026
Accepted: 8 May 2026
Available online: 12 June 2026

Abstract: Introduction: Obstetrics and gynecology is a highly practice-oriented and conceptually complex discipline, yet traditional teaching is limited by hidden anatomy, restricted clinical exposure, and ethical constraints. The metaverse, as an immersive and interactive digital learning ecosystem, offers new opportunities to overcome these challenges. This study aims to explore its educational value and propose a structured framework for its application in obstetrics and gynecology teaching. **Methods:** This study was conducted in accordance with the PRISMA guidelines. Relevant literature published between 2010 and 2026 was systematically retrieved from the PubMed and Web of Science databases. By integrating the characteristics of the metaverse with the educational requirements of obstetrics and gynecology, and guided by constructivist learning theory, we propose a metaverse-based teaching model that combines immersive virtual environments, interactive learning scenarios, and simulated clinical practice. **Results:** Metaverse-based education demonstrates significant potential in obstetrics and gynecology training. Immersive three-dimensional visualization improves understanding of complex anatomy and physiological processes, narrowing the gap between theoretical knowledge and clinical practice. Interactive simulation environments enhance learner engagement, motivation, self-efficacy, and knowledge retention. High-fidelity virtual scenarios enable safe and repeatable training in clinical procedures, emergency management, decision-making, and teamwork. A comprehensive framework integrating cognitive theory, instructional design, and competency-based evaluation was identified. However, implementation is limited by technological constraints, high cost, digital inequity, cognitive overload risk, lack of standardized assessment systems, and unresolved ethical and data security issues. **Conclusion:** The metaverse has the potential to transform obstetrics and gynecology education from traditional knowledge transmission to immersive, competency-based, and data-driven learning. While current evidence supports its educational benefits across cognitive, procedural, and behavioral domains, large-scale implementation requires further technological maturation, standardized evaluation systems, and robust ethical and regulatory frameworks.

Keywords: Metaverse, Obstetrics and gynecology, Medical education, Teaching model

1. Introduction

The term metaverse was originally mentioned in the science fiction novel “Snow Crash” by Neil Stephen in 1992, where Stephen employed the word to describe a virtual reality based successor to the Internet[1]. The metaverse is an artificially constructed parallel to the real world consisting of a myriad of interconnected virtual communities characterized by being real in time and virtual in space[2]. Concisely, the metaverse should not be narrowly interpreted as merely the use of virtual reality devices or a single form of immersive technology. Rather, it should be conceptualized as a persistent, multi-user, and highly interactive digital learning ecosystem. Our review defines the metaverse through four core pillars: persistent multi-user worlds for social learning, AI-supported tutoring agents for personalized guidance, digital twins for high-fidelity clinical replicas, and data analytics for longitudinal competency tracking. Crucially, we exclude single-user, non-persistent VR modules—which function as isolated digital assets—from this definition, as they lack the synchronous connectivity and temporal continuity essential to the metaverse paradigm[2,3]. Although the concept has been widely discussed in technological and industrial fields, its systematic application in medical education—particularly in disciplines requiring high levels of practical engagement and contextualized learning—remains at an early stage. Existing studies tend to focus on technological architectures and societal implications, whereas limited attention has been given to how the metaverse may reshape core components of medical training such as clinical reasoning, procedural competence, communication skills, and professional identity formation.

The proposal of metaverse is a reflection on the development of future society, the core of which is to simplify the experience of daily life, such as cognition, emotion, and behavior of human users, into computational logic and rules. The emergence of metaverse presents an innovative paradigm for the living of people. By integrating the reality and the digital binary world, the metaverse technology facilitates the expansion of people's perceptions, empowers more people as beneficiaries and sharers of the digital transformation, and strengthens the satisfaction of their lives, in turn realizing the data-driven smart urbanism[4]. Within the metaverse, concepts of not only lifestyle reconfiguration, but also the traditional economy are confronted with an all-encompassing economic grand transformation, whereby the rules of science and technology themselves will encroach upon, influence, and alter a range of traditional economic routines. In the educational domain, this "immersive–interactive–contextual" paradigm is particularly meaningful, as learning is fundamentally a cognitive and emotional process of knowledge construction. The immersion, immediate feedback, and repeatability enabled by the metaverse offer opportunities to operationalize core educational theories—such as constructivism, experiential learning, cognitive load theory, and self-determination theory—within medical training, thereby enabling learners to build knowledge in authentic clinical contexts. Extant research has demonstrated that this 'repetitive training–immediate feedback' pedagogical model significantly enhances students' clinical reasoning, procedural comprehension, and academic engagement [5,6].

In the field of healthcare, metaverse can utilize its powerful advantages in the diagnosis and treatment of diseases, as the literatures have shown that VR and AR technologies stand out as a promising tool in the management of patients with a psychotic disorder to improve their clinical outcomes[7].Furthermore, metaverse can also be considered as a distant medical platform, which can realize the breakthrough of the bottleneck of the lack of medical resources in remote areas at the technical level, improve the medical level of remote areas, and boost the health index of the whole populations[8]. At the same time, an increasing number of studies suggest that metaverse technologies can substantially enhance the training of healthcare professionals, including preoperative rehearsal, three-dimensional anatomical visualization, teamwork simulation, and performance analytics. However, most existing evidence is concentrated in general surgery, neurosurgery, and psychiatry. Systematic investigations of metaverse-based education in obstetrics and gynecology—a discipline characterized by technical complexity, emergency-driven scenarios, and high ethical sensitivity—remain limited, highlighting a significant research gap.

Education refers to the transmission of human knowledge, which is generated in a real knowledge application environment, providing an important way to acquire quality knowledge through educational and practical activities. While school education is the most advanced approach to the continuation and development of knowledge, it is difficult to provide medical students with a practice environment that allows them to experience the process of knowledge construction due to the constraints of school space, curriculum time, and resource environment configuration. This challenge is particularly prominent in obstetrics and gynecology education, where clinical workload, patient privacy, ethical concerns, and the sensitive nature of reproductive examinations restrict students' opportunities for hands-on practice. As a result, learners often report insufficient exposure to pelvic examinations and limited participation in high-risk obstetric emergencies such as shoulder dystocia or postpartum hemorrhage, which may compromise their confidence and competency development. This problem can be remedied by the emergence of metaverse, which can connect the past, present and future real worlds, build authentic educational contexts, allow learners to experience the actual problem solving process, gain practical perception, recognize the world and transform the world in practice, and then realize the closed-loop of knowledge creation. Within metaverse-based environments, learners can repeatedly engage in clinical decision-making and procedural skills in three-dimensional, safe, and standardized simulated spaces. Through digital twins, intelligent feedback systems, and realistic scenario reconstruction, the metaverse supports the development of competency-based, data-driven, and personalized medical learning pathways.

Together, it also implies that the pedagogical form of knowledge transmission, the way students learn and the value of their study experience will also change. So what does the metaverse mean for the future of medical student education, and what are the opportunities and challenges it will face, are questions that have yet to be answered. Particularly in obstetrics and gynecology—where procedural proficiency, emergency responsiveness, and sensitive-exam communication are essential—the introduction of the metaverse may reshape instructional models, competency assessment, and the value of learning experiences. Nevertheless, a comprehensive review synthesizing educational, technological, and specialty-specific perspectives is still lacking. Therefore, this review aims to address this gap, summarize existing evidence, and propose future directions for the application of metaverse technologies in obstetrics and gynecology education (**Figure 1**).

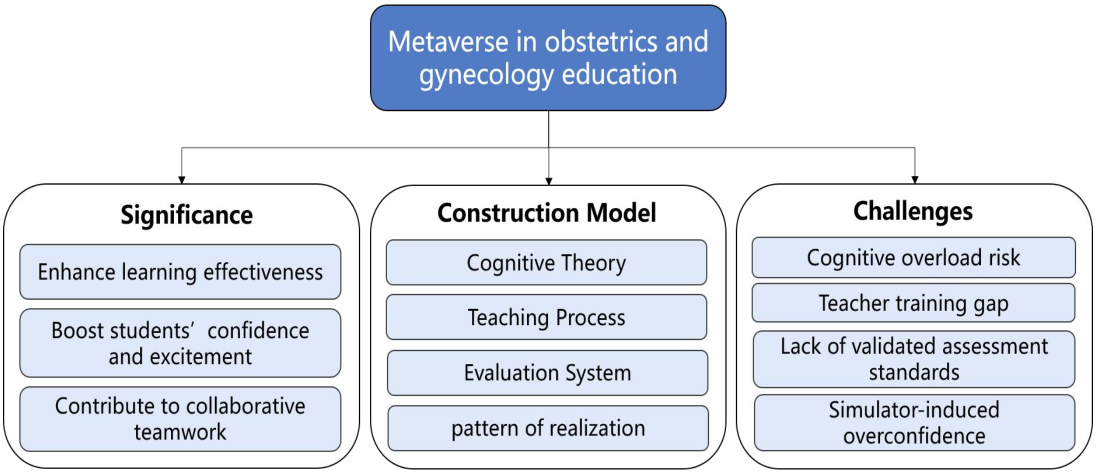

Figure 1 The workflow of the metaverse in obstetrics and gynecology education.

2. Methods

2.1 Research Design and Search Strategy

This systematic review aims to evaluate the evidence regarding the application of Metaverse technologies within obstetrics and gynecology (O&G) medical education. To ensure methodological rigor and reproducibility, the study protocol was developed in accordance with the PRISMA guidelines. The search spanned academic literature published between 2010 and 2026, primarily utilizing the PubMed and Web of Science databases.

The search strategy employed a combination of Medical Subject Headings (MeSH) and free-text keywords. The core search logic was structured around the following three domains:

Domain A (Technology): "Metaverse" OR "Virtual Reality" OR "VR" OR "Augmented Reality" OR "AR" OR "Mixed Reality" OR "MR" OR "Digital Twin" OR "Immersive Technology."

Domain B (Discipline): "Obstetrics" OR "Gynecology" OR "Maternal-Fetal Medicine" OR "O&G" OR "Labor and Delivery."

Domain C (Education): "Medical Education" OR "Surgical Training" OR "Residency" OR "Simulation-based Learning" OR "Competency-based Education."

2.2 Inclusion and Exclusion Criteria

To identify high-quality and relevant literature, the following stringent inclusion and exclusion criteria were established:

Inclusion Criteria

a.Studies exploring the application of Metaverse, VR, AR, or MR technologies specifically within the context of medical education.

Exclusion Criteria

a.Non-academic articles, editorials, commentaries, or reports that have not undergone formal peer review.

b.Duplicate publications or studies with incomplete data sets.

2.3 Study Selection and Data Extraction

Initial records were screened by two independent researchers based on titles and abstracts. Subsequently, the full texts of potentially eligible studies were retrieved and thoroughly reviewed to verify their compliance with the final inclusion requirements.

For the studies ultimately included, we extracted the following key data attributes for comprehensive analysis:

a.General Information: Author(s), year of publication, and country of origin.

b.Pedagogical Attributes: Target learner population and specific clinical sub-specialty.

c.Technical Attributes: Hardware specifications, software platforms, and interactive features.

d.Evaluative Attributes: Assessment methodologies, primary research findings, and identified limitations.

3. The significance of the metaverse theory for obstetrics and gynecology education

3.1 Metaverse enabling obstetrics and gynecology education more stereoscopic

Obstetrics and gynecology is a medical course that is closely linked to theoretical knowledge and practical operation, with extremely professional, realistic and manipulative. The current teaching mode of obstetrics and gynecology is dominated by the teacher's lectures in large classes, with PPT as the main teaching tool, which is a very boring mode of indoctrination, and the atmosphere of learning dull, hardly mobilizing the students' enthusiasm for learning. Furthermore, Obstetrics and Gynecology involves special anatomical location, high content difficulty, complex theoretical knowledge and extensive scopes, which greatly reduces the students' ability to understand, digest and absorb the course content in the classroom. Above all, the theoretical content alone is rarely capable of arousing students' sense of transformation of theory into practical problems and when confronted with the diagnosis and treatment of actual patients, medical students cannot reasonably and skillfully transfer the knowledge from books into clinical knowledge for personal use, nor can they build up their own clinical thinking patterns. From an educational perspective, this gap between “knowing” and “doing” reflects a common challenge in traditional medical education. In obstetrics and gynecology—where anatomy is hidden, operative space is narrow, and clinical scenarios are highly contextual—students are even more prone to the learning dilemma of “being able to recite but unable to perform” or “being able to operate but lacking conceptual understanding” .

Based on this, the metaverse concept proposes that the theoretical knowledge can be presented more vividly and three-dimensionally from the teaching mode with the assistance of virtual technology such as AR, VR, and so on, in which students can explore the wonders of obstetrics and gynecology actively from the first viewpoint, an excellent grip on the theoretical learning of obstetrics and gynecology. Such as the labor process of occipital presentation, which includes a series of complex spatial position transitions of the fetus in the birth canal, with the support of the metaverse principle, students can intuitively break the imagination of the process, and deepen their understanding and grasping of knowledge at the visual level.

In terms of learning efficiency, there are literatures that demonstrate that the teaching of anatomy based on VR technology is much more effective than the traditional or 2D teaching mode, and anatomy is the theoretical foundation of obstetrics and gynecology, which gives reason to assume that this technology can greatly improve the learning efficiency of obstetrics and gynecology, and at the same time, this strategy enhances the interactions between students and teachers, and allows for peer-to-peer responses to students' queries in a significantly improved and more efficacious manner[9]. Furthermore, immersive visualization can reduce extraneous cognitive load and help students master complex structures via spatialized cognition, aligning with Cognitive Load Theory and supporting deeper conceptual understanding.

Moreover, in parallel to the increased learning efficiency, the concept of metaverse also contributes to the enhancement of students' learning skills and facilitates the retention of prior memorization of such acquired information in the long term. It has been observed that leveraging simulation training in surgical education significantly improves the prolonged retainment of surgical education skills, and the literature contends that the repetitive and immersive nature of such simulations fosters long-lasting learning[10]. Taking an extended perspective, it is not only the immediate learning competencies that are developed, but as medical students grow into doctors, VR technology can sharpen their decision-making and problem-solving powers, which are essential qualities for being an outstanding doctor[11]. In obstetrics and gynecology emergency scenarios—such as shoulder dystocia, cord prolapse, or postpartum hemorrhage—VR can provide repeated, risk-free rehearsal of critical steps, reinforcing procedural memory and improving real-world response speed.

3.2 Metaverse boosts the confidence and excitement of students learning

The essence of medicine is the process of experience accumulation, which requires exposure to a large number of clinical patients and operational cases from which to gather experienced, and the traditional apprenticeship teaching program hinders the inheritance of medicine due to the refusal of some patients to become examples of clinical teaching[12]. The proposed concept of metaverse can well circumvent this risk, the flexibility and reproducibility of digital technology allows medical students to be more relaxed to deal with clinical patients, and to devote themselves to medicine with a more positive attitude to learning, which will not cause certain psychological pressure on students, and will enhance their confidence and interest in learning, meanwhile it also guarantees the safety of patients, and the metaverse plays with an important role in balancing the teaching of medicine and the security of patients[13,14]. In addition, the metaverse notion also renders the teaching process interactive, which can shorten the learning feedback period and achieve the purpose of immediate feedback, and contribute to awakening and stimulating students' learning motivation, clarifying the studying goals and revising the learning program. There are studies indicating that remarkable positive correlation exists between students' learning motivation and their academic performance, and when the learning enthusiasm is more elevated, the more excellent the students' achievements are[15]. According to Self-Determination Theory, immersive digital environments enhance learners' autonomy, competence, and relatedness—three key psychological needs that drive deep learning engagement. In the field of neurosurgery, the superior technical quality and detailed surgical procedures available with VR technology have resulted in 81% of medical students expressing an increased interest in neurosurgery, and 47% acknowledging the potential impact of this technology on their future specialty choices[16]. Similarly, in obstetrics and gynecology, VR/AR can increase student engagement in sensitive or technically demanding tasks—such as pelvic examinations, labor assessment, or cervical dilation evaluation—reducing anxiety and improving self-efficacy.

3.3 Metaverse contributes to the development of collaborative teamwork in students

Medicine is the discipline that demands teamwork, and this kind of cooperation exists between doctors and doctors, directors and students, doctors and nurses. It is precisely because of this mode of efficient collaboration and teamwork, that patients can be relieved of their pains quickly in the face of clinical diseases. The proposal of the philosophy of metaverse is more compatible with the current mode of operation, based on the virtual education environment of the metaverse, medical students not only strengthen their own practical ability, but more importantly, they can clearly define their own division of labor, as well as their position and responsibilities in teamwork, and more emphasis on teambuilding. On the basis of the specificity of clinical medicine, the teaching process will involve the corresponding tools, if the cooperation is not appropriate, there will be the risk of accidentally injuring other students or teachers. The virtual space provided by the metaverse serves as a “risk-free trial stage” for early teamwork training, allowing students to practice coordination in a safe and relaxed environment. This is particularly valuable for obstetrics and gynecology scenarios requiring tight collaboration—such as managing postpartum hemorrhage as a multidisciplinary team or coordinating roles in an assisted vaginal delivery. This spatial virtualization of the metaverse happens to play a protective role in the teething stage of teamwork, which facilitates medical students to devote themselves to teamwork in a more relaxed state of mind and assists in the improvement of clinical work efficiency. Moreover, through digital-twin technology, team members’ movements, communication patterns, task allocation, and response times can be visualized and quantified, providing objective metrics for competency-based assessment of teamwork skills.

3.4 Framework of metaverse applications in obstetrics and gynecology education

In summary, by integrating VR, AR, and digital twin technologies, the metaverse provides a novel paradigm for obstetrics and gynecology education, transitioning from traditional “two-dimensional knowledge delivery” to a “three-dimensional immersive learning experience.” At the knowledge level, it significantly enhances the visualization of complex anatomical structures and dynamic physiological processes, thereby bridging the gap between “understanding” and “execution.” At the learner level, immersive and interactive environments effectively improve learning motivation, self-efficacy, and long-term knowledge retention. At the competency level, it offers repeatable and low-risk training scenarios for clinical decision-making, emergency management, and teamwork. This multidimensional transformation of teaching not only aligns with the competency-based trend in modern medical education but also addresses the longstanding challenges of high complexity and strong contextual dependency in obstetrics and gynecology training.

The metaverse should not be regarded as the application of a single technological tool, but rather as a comprehensive framework that systematically reshapes medical education. Its advantages are particularly evident in obstetrics and gynecology, a discipline that heavily relies on contextualized practice and experiential learning. To more clearly illustrate these multidimensional benefits and to specify their application pathways and expected outcomes across different teaching stages, this study further summarizes and integrates the key elements of metaverse-enabled obstetrics and gynecology education (**Table 1**), with the aim of providing a structured reference for future educational practice and research. For instance, a "Pelvic-exam

Vignette" utilizes a low-cost HMD and a basic haptic trainer; students navigate a self-paced anatomy module, followed by a supervised simulation where AI agents provide real-time anatomical prompts, concluding with an OSATS-based assessment within the pre-clinical skills lab. Similarly, an "Obstetric Emergency Drill" employs full-scale XR where a multidisciplinary team manages a virtual postpartum hemorrhage; the session focuses on communication and protocol adherence, integrated into the residency emergency simulation curriculum.

Table 1. Metaverse Applications in Obstetrics and Gynecology Education

Solution Dimension	Specific Measures and Technical Approaches	Expected Benefits	Implementation Barriers	Evaluation Indicators
Clinical Skills Simulation	VR/MR-based simulators for delivery and surgery (e.g., hysteroscopy), as well as obstetric emergencies (e.g., shoulder dystocia, umbilical cord prolapse), integrated with gesture interaction and haptic feedback devices [17]	Shorten learning curve; improve skill proficiency and surgical success rate; reduce reliance on real patients and minimize medical risks [18]	High hardware cost (VR headsets, computing devices); complex development of realistic haptic feedback and soft tissue simulation; long development cycle [19]	Operational metrics (task completion time, operation accuracy, error count); physiological metrics (force feedback, motion trajectory); pass rate before clinical practice [20]
Theoretical / Anatomical Visualization	3D holographic projection or VR-based visualization of fetal, uterine, and pelvic anatomy, enabling spatial understanding beyond traditional 2D images [21]	Improve spatial anatomical understanding and knowledge retention; reduce dependence on physical specimens [22]	Visual fatigue and dizziness; long development cycle for high-quality 3D models; high teaching adaptation cost [23]	Cognitive assessment (test scores, recognition accuracy); learning experience (SUS score, satisfaction, dizziness incidence); long-term retention (3–6 months follow-up)
Clinical Reasoning and Decision Making	Virtual standardized patients simulating obstetric emergencies (e.g., postpartum hemorrhage, placental abruption); trainees perform diagnosis and decision-making in high-pressure environments [24]	Provide zero-risk training for high-risk/low-frequency cases; improve emergency response and multitasking ability; compensate for uneven clinical exposure	Standardization difficulty; high development complexity requiring interdisciplinary teams; immature natural language interaction [24]	Decision timeliness; protocol compliance rate; team collaboration performance in multi-user environments
Communication and Humanistic Literacy	VR/AR-based doctor–patient communication scenarios (e.g., condition disclosure, breastfeeding counseling such as LactaVerse) to train empathy and communication skills [25]	Improve empathy, communication, and counseling ability; allow repeated practice in low-stress environments; more standardized than role-play [25]	Emotional simulation limitations; subjective evaluation; privacy and ethical concerns in data handling	Communication quality scores; empathy scale changes; patient satisfaction; self-efficacy assessment [25]

Continuation Table:

Solution Dimension	Specific Measures and Technical Approaches	Expected Benefits	Implementation Barriers	Evaluation Indicators
Management and Workflow Drills	Virtual delivery rooms or operating theaters simulating multidisciplinary collaboration (obstetrics, anesthesia, neonatology) for emergency drills (e.g., C-section, hemorrhage resuscitation) [26]	Improve teamwork, role clarity, and emergency efficiency; reduce errors; enable remote collaborative training	Network latency; equipment and space requirements; lack of realistic physical interaction	Team collaboration metrics; process time; error rate in critical steps [26]
Faculty Training and Teaching Management	Unified metaverse teaching platforms supporting virtual lesson creation, real-time monitoring, standardized scoring, and feedback [27]	Standardize teaching processes; reduce variability across instructors; expand access to high-quality teaching resources [28]	Variability in faculty digital literacy; additional training cost; difficulty integrating with traditional curricula [27]	Teaching efficiency; consistency of teaching quality; teacher satisfaction

4. The construction of the metaverse obstetrics and gynecology pedagogy

4.1 Metaverse Instructional Model of Cognitive Theory

The teaching pattern of metaverse unified based on virtual technology is the preferred solution for the contextual cognitive teaching style within the scope of the contemporary constructivist learning strategy. The dissemination of medical science knowledge is summarized from theoretical content combined with the clinical experience of predecessors, and medicine is also referred to as empirical medicine, while constructivism points to this process of re-constructing new knowledge on the foundation of previous memory. The constructivist perspective of learning simply states that medical students are not only receiving knowledge in a passive manner, but also have to organize, manipulate, and assimilate new learning in accordance with their own background experience, and that this is a reconfiguration procedure of understanding knowledge[29]. When confronting with different sources of problems, students are required to reformulate and reconstruct their established known knowledge in the current situational format in response to the emerging requirements. Metaverse-based learning transcends traditional models by deconstructing spatio-temporal limits and providing granular, real-time feedback[30]. Unlike experiential learning constrained by scarce physical practice, it utilizes digital twins for infinite, high-fidelity simulations that turn abstract reflection into visual correction.Moreover, it shifts the focus from outcome-based assessment to process-based evaluation. By leveraging IoT and AI to capture millisecond-level data, the model bridges the gap between theory and practice[31]. This transition from "knowledge acquisition" to "embodied cognition" marks a paradigm shift from standardized testing toward precision-driven competency development. Teaching theory, methodology, and pattern under the guidance of constructivist learning theory are all centered on situational construction where teachers with external information resources, such as VR,AR,MR and other virtual technologies, are required to supply a simulated learning scenario, in which students can fully integrate the resources and take the initiative in acquiring new knowledge. The realization of the Metaverse relies on a hardware-software ecosystem categorized into four dimensions: XR terminals for sensory interaction, IoT/3D sensors for physical-virtual mapping, 5G/6G networks for low-latency transmission, and AI/GPU clusters for computational power[32]. To operationalize this ecosystem, we propose a four-stage implementation sequence for educators: (1) Starter Setup: utilizing LiDAR and 3D scanners to facilitate 3D anatomy visualization during pre-clinical years; (2) First Pilot Skill: employing IoT sensors for task-specific simulations, such as fetal heart rate monitoring, prior to real patient contact, where success is defined by achieving a >90% score on skill-specific checklists; (3) Integration Point: leveraging 5G networks and edge computing to support multi-user OSCE preparation sessions, targeting a 20% increase on validated confidence scales; and (4) Evaluation Milestone: utilizing dedicated AI chips and GPU clusters to drive high-fidelity emergency drills for senior residents, with success measured against predetermined procedural error-rate targets. Together, these infrastructures and milestones facilitate a paradigm shift toward a persistent, synchronized digital existence that ensures data-driven competency development. This spatial virtual characteristic of metaverse, and the adaptability degree of situational cognitive teaching mode is maximized in the field of medical education, which can deliver a multitude of plot schemas, and even construct extreme situations that are rare in clinic, which enables the students to construct knowledge with a broader horizon, and not have to be overwhelmed when dealing with clinical emergency and serious illness problems. Therefore, the metaverse instructional pattern is the most contemporary and compatible with the constructivist perspective on learning.

4.2 Metaverse Educational Model of Teaching Process

The metaverse characterization of temporal reality and spatial virtualism enable it to play an obvious advantage in comparison with the traditional scenario-based teaching. According to the metaverse system, teachers and medical students can appear together in the same teaching scenario regardless of their spatial location, and the reproducibility of this digital technology will also facilitate the choice of learning time for medical students(**Table S1**). The instructional procedure of metaverse mainly includes the following six aspects: formulating teaching objectives and contents, designing teaching strategies and scenarios, entering the metaverse environment, exploring and interacting with teachers and students, practicing skills after class, and forming evaluations and feedbacks (**Figure 2**). What this requires is that teachers and medical students participate in the metaverse teaching model together.

To begin with, teachers need to establish learning objectives and components of study for practical skills according to theoretical knowledge and curriculum planning, as well as to design scenario models and teaching strategies that are essential for teaching and furnish practice scenarios. In the second place, students do need to break through the boundaries of thinking, integrate new knowledge on the level of previous content, and construct a new set of learning modes. Most importantly, teachers and students interact, communicate, and explore the world of the metaverse together with the helpline of the virtual technology, and moreover, the reproducibility and interactivity of this technological platform will benefit the students' practicing and reviewing after the class. For the purpose of more targeted teaching and mentoring, the assessment mode will also be present in the metaverse world, and the evaluation results will be delivered back to the teacher's side and the student's part respectively through the feedback mechanism, where the teachers will be responsible for adjusting the learning objectives and studying contents, and the students will be in charge of reinforcing the weak knowledge points and practicing accurately. In general, through the teaching process in the metaverse, more efficient and precise teaching activities can be carried out to realize the teaching goal of win-win situation for both teachers and students.

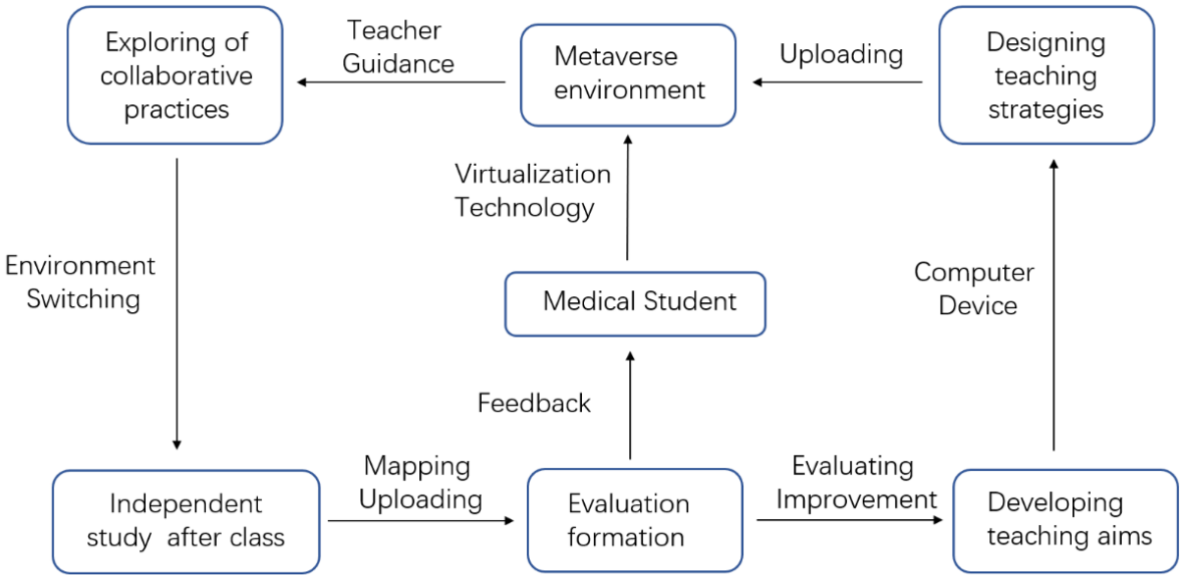

Figure 2 The Educational Process in the Metaverse Model.

4.3 Metaverse Teaching Model's Evaluation System

The evaluation system of the metaverse teaching pattern is of multidimensionality, which consists of the appraisal of the instructor's teaching quality, the assessment of the students' knowledge acquisition, and the appreciation of the course design. The central core of the metaverse is virtual technology, and the assessment system of the metaverse is assessed based on the technology, which can quantify every part of the teaching process, and can indicate the effectiveness of the teaching through intuitive data, simplifying the assessment workflow and promoting rapid and precise feedbacks to teachers and students, and continuously refining the teaching process. Apart from that, the most outstanding performance of the metaverse education mode compared with the traditional teaching pattern is that the metaverse instruction style can criticize the post-class learning. In the traditional teaching mode, teachers cannot grasp the students' after-school learning situation at any time, and are unable to master the students' acceptance and digestion status of new knowledge well, which leads to the teachers' lack of clarity in designating the curriculum and educational content, and fails to solve the students' real confusions well. Under the metaverse model, students' after-class activities can be well recorded and timely feedback can be sent to the instructor, which in turn aids in specifying the teaching program and adjusting the instructional content with precision.

Education assessment under the metaverse model is carried out throughout the whole process of obstetrics and gynecology curriculum, which encompasses not only the evaluation of students' learning during and after each lesson, but also the staged and summative evaluations of the overall program. Thus, each of students' class progress, accompanying practice and homework after class are recorded exactly, and the completion of those sub-tasks will also be documented as assessment score points, which would be more comprehensive, quantitative and accurate for the integrated evaluation.

4.4 Metaverse Teaching Pattern Realization

The metaverse is not limited to a single technology or platform, it includes technologies such as artificial intelligence, virtual reality, augmented reality, mixed reality, blockchain, etc[33]. Artificial intelligence assistants, represented by ChatGPT, are excellent solutions for instant tutoring and feedback to students and complement learning outside the classroom that is not covered by traditional teaching models[34].

VR technology creates an immersive digital environment that breaks through the limitations of the physical world, and it permits learners to interact and experience in an immersive way[35]. VR technology can support medical students to learn anatomical samples in a more three-dimensional way and understand complex anatomical structures more efficiently[36]. The simulation training provided by VR technology also augments the operative abilities of surgical students and can strengthen their clinical decision-making skills[37]. Alternatively, this technology can frame student-patient interactions in clinical work, where students learn about diagnostic rationalizations, and communication with patients[35]. AR refers to the addition of images, 3D, and other elements that empower users to enhance their perception and understanding of their surroundings in the real world.AR can be employed in medical imaging which directly maps 3D images from medically scanned objects onto individual patients, which can assist in visualization and development of surgical protocols[35]. MR combines the features of AR and VR so that both the digital environment and the real world can be interacted with and manipulated by the consumer, which can commonly play a role in the team coordination and collaboration that is involved in clinical emergencies. The maturation of these technologies is fundamental to the metaverse educational model and the cornerstone of the metaverse philosophy. The metaverse pedagogical pattern will be construction in terms of auditory, visual, tactile and perceptual reality, while the formation of the metaverse would be a revolutionary event in the history of education and pedagogy.

5. The challenges of metaverse education in obstetrics and gynecology

The metaverse was proposed to integrate educational resources and empower students to break the constraints of academic time and geography, but the technological model on which the metaverse relies is likely to exacerbate inequities in education, with some impoverished areas lagging further behind in their access to educational resources due to their inability to be equipped with the appropriate devices. Some medical students with visual or hearing deficiencies may also encounter obstacles to learning, which further challenges the inclusiveness of the metaverse to ensure that all students have the opportunity to have a fair educational experience. In obstetrics and gynecology education, this inequity may be further amplified, as many learning scenarios rely heavily on immersive visual details and spatial perception, such as complex pelvic anatomy and operative depth cues.

Connectivity is the cornerstone of virtual education, and the educational metaverse has required extensive networking and technological applications in the process of its utilization and implementation, and when this connectivity is challenged it can prevent medical students from experiencing the benefits of this metaverse educational model in regions that do not have reasonable access to the Internet and related technologies[38]. At the current stage, the education model of metaverse is still immature, the development of the equipment on which it depends has not reached a flourishing period, and the available equipments are still not portable and have the certain difficulty of operation, and at the same time, the education-related softwares still have the partial functions that cannot be implemented, and are incompatible with the hardware facilities and so on, which will dramatically have an impact on the operating experience of the users and the learning efficiency of the students, and the stabilization of the performance of such devices would continue to require repeated trials and tribulations under the prevailing conditions of macro-data in the market. Moreover, technical instability, latency, and excessive sensory input may increase learners' cognitive burden, introducing a risk of cognitive overload that could impair learning effectiveness, particularly in cognitively demanding obstetrics and gynecology scenarios.Despite its grand vision, the Metaverse faces significant limitations across technical, structural, and ethical dimensions. Hardware bottlenecks remain a primary hurdle, as current XR devices struggle to balance weight, battery life, and resolution, often causing motion sickness and diminishing user comfort. Structurally, the ecosystem is plagued by "siloing," where a lack of unified protocols prevents the seamless interoperability of digital identities and assets across platforms[39].Furthermore, legal and ethical frameworks remain underdeveloped, leaving issues like data ownership and algorithmic bias unresolved. In specialized fields like medical education, the use of unverified AI-generated synthetic data poses risks of clinical inaccuracy. Finally, the immense computational and bandwidth requirements create a high barrier to entry, potentially widening the digital divide and exacerbating inequality in access to advanced educational resources.Beyond that, the issue of the price of such advanced devices is another linchpin that undermines the popularity of metaverse instruction, especially for districts that suffer from a lack of resources to benefit from this technologically advanced ecosystem, the metaverse can compound the financial burden of medical education for the individual or the country, which may also narrow the possibilities of a segment of the population of learners, thus curtailing the merits of the metaverse educational model[40, 41]. In parallel, this shift from traditional teaching methods to one that is reliant on pedagogical devices also poses a challenge for teachers and students, with teachers needing to master the use of new technologies while completing the content, and students adjusting to this new learning instrument and school environment[42]. In obstetrics and gynecology education, heavy clinical workloads and heterogeneous digital literacy among faculty may further widen the teacher training gap, potentially compromising the quality and consistency of metaverse-based instruction.

There are also technical challenges of data security in the metaverse teaching model in that metaverse technology necessitates the support of a substantial amount of data, and there is as yet no certainty that all of this data has been permitted by local ethics committees, and there is no way of knowing whether or not the security of this acquired data can be fully assured in the context of the large-data paradigm. The clinical education of medical students will inevitably be supported by the availability of data from hospital patients, and the effective management of sensitive medical data in a virtual environment is subject to rigorous security procedures, not only for the protection of patients' private information, but also for the regulation of healthcare legislation[43]. Establishing stringent security criteria to protect this scholarly and sensitive data and to safeguard the integrity of educational platforms is imperative and the implementation of such guidelines engages academic institutions, technology companies, and cybersecurity specialists to continually assessment that security infrastructure and refine on an ongoing basis[44]. Given that obstetrics and gynecology data often involve highly sensitive reproductive and maternal health information, breaches in this context may carry particularly serious ethical and legal consequences.

The metaverse is a prospective trustless environment, which places responsibility and accountability at a premium in the metaverse space, where we can identify and protect patient data with the help of technological tools such as blockchain. Further, we have to recognize the issue of data ownership in the metaverse model, and there is no doubt that the clinical data is still in the hands of the patient in this virtual environment.

Teachers and medical students are the main participants in the metaverse teaching model, which allows that we have to assign an identity to the characters of the participants, in order to constrain the behavioral limitations of the individuals in the virtual world, and to explicitly detect the identity of the offenders in some situations involving illegal activities, which in turn can discipline the behavior of the subjects from the legal level. However, immersive simulation environments may also lead to simulator-induced overconfidence, whereby learners overestimate their competence based on repeated success in virtual settings, potentially underappreciating risks in real clinical practice—an issue of particular concern in high-risk obstetrics and gynecology procedures. In Metaverse-based Obstetrics and Gynecology education, data security and ethics are paramount, requiring a multi-layered privacy safeguard architecture[4]. To handle sensitive information, the system must prioritize the use of AI-generated synthetic patient data to simulate complex clinical scenarios, thereby bypassing privacy risks at the source. When real clinical data is utilized, it must undergo multi-level de-identification to ensure anonymity. Security controls are maintained through Role-Based Access Control (RBAC) and comprehensive audit trails to monitor data interaction. For highly sensitive procedures, such as pelvic examinations, we advocate for a "physical isolation" strategy, deploying simulations on secure, on-premise servers rather than public clouds to ensure closed-loop management and regulatory compliance. Ethical governance is managed via a dedicated oversight pathway, where institutional review boards and digital teaching ethics committees provide formal approval and continuous audit of access protocols. For institutions where high-end XR infrastructure or on-premise servers are not feasible, we propose a "Low-Resource Pathway". This approach utilizes browser-based 3D simulations (WebXR) compatible with existing hardware, such as smartphones paired with low-cost cardboard head-mounted displays. To maintain security without expensive servers, the model transitions to decentralized, anonymous local data storage or the use of open-source de-identified datasets. This "mobile + shared service" mode ensures that even in resource-limited settings, students can engage in interactive, high-quality learning without compromising the security of sensitive reproductive health information or patient dignity. Furthermore, the lack of validated assessment standards for metaverse-based education—including objective measures of procedural performance, teamwork quality, and long-term competency acquisition—poses a significant challenge to the reliable evaluation and large-scale implementation of this educational model.

6. Conclusion

The integration of the metaverse into the instruction of obstetrics and gynecology will be a substantial advancement in medical education and has the potential to revolutionize all aspects of obstetrics and gynecology instructional delivery. In the metaverse, all sorts of digital technologies can support teachers and students to perform their respective roles and accomplish their tasks more accurately and efficiently by providing teachers with more appealing teaching programs, adjusting learning contents and schedules without any delays, and more conveniently and comprehensively evaluating the learning process of the students. While the students may be more three-dimensional in learning and mastering theoretical knowledge, flexible in utilizing the practical skills learned, and more authentic in participating in clinical activities and collaborative work with them. Although there are certain challenges in the current stage of the metaverse educational model, the medical students under the cultivation based on the metaverse instructional pattern are the most in line with the background of the current period of time, and it is the fundamental to contribute to the construction of universal health care circumstances.

Acknowledgements: The authors are grateful for the opportunity to conduct this study and write this paper, and the authors appreciate the kind support and encouragement received from the academic and research community.

Author contributions: Conceptualized and directed all the research, JXL; paper search and the initial draft, LBM; drafting of the manuscript and provided feedback throughout the process, WX and JYM; supervision and editing, WJL. All authors reviewed and approved the final version of the manuscript.

Funding: This work was supported by the Teaching Reform Open Research Grant of The Second Clinical College, China Medical University (Grant No. SJJG-2025KFQN05 for Lingbo Meng)

Conflict of interest: All authors have no conflict of interest in the publication of the review.

Data availability: No data is associated with this review.

Clinical trial number: Not applicable.

Ethics declaration: Not applicable.

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