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TECHNOLOGICAL EVOLUTION AND PEDAGOGICAL SHIFTS IN PREGNANCY SIMULATION TOOLS: A SCOPING REVIEW

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ABSTRACT

Technological advancements have fundamentally reshaped midwifery and maternity nursing education. While traditional simulation has been long established, the emergence of digital innovations such as Virtual Reality (VR) and Artificial Intelligence (AI) necessitates a clearer understanding of evolving technological trends and their associated pedagogical shifts. This study aims to map contemporary pregnancy simulation tools and identify the targeted learning objectives within these modalities. A scoping review was conducted utilizing the Arksey and O'Malley framework and adhering to the PRISMA-ScR guidelines. A systematic search was performed across six databases (Scopus, PubMed, Springer Nature, ScienceDirect, ERIC, and Google Scholar) for literature published between 2015 and 2026. From the 663 records initially identified, 9 selected studies were thematically analyzed to extract data regarding technological classification and pedagogical orientation. The findings identified four major categories of pregnancy simulation technologies: analog and physical (wearable) simulators (n = 1); high-fidelity and hybrid simulators (n = 2); immersive technologies, including VR and AR (n = 2); and AI-based simulations integrating generative AI and telehealth (n = 2). Across these categories, all studies utilized interactive simulation approaches, with most demonstrating high-fidelity characteristics. Four dominant pedagogical orientations were identified: empathy and attitudinal development (n = 1); self-confidence and anxiety reduction (n = 1); psychomotor and clinical skill acquisition (n = 2); and critical incident competence and cultural responsiveness (n = 2). A clear shift was observed from empathy-focused learning toward the development of complex clinical competencies, psychological readiness, and adaptive communication skills. This evolution reflects a transition in simulation fidelity from predominantly physical realism to interpersonal fidelity, enabling integrated development of technical and relational competencies. Pregnancy simulation technologies have evolved from physical wearable devices to high-fidelity manikins, immersive VR/AR systems, and AI-driven telehealth simulations, forming increasingly intelligent and interactive learning ecosystems. Concurrently, pedagogical orientation has shifted from affective learning toward performance readiness, clinical decision-making, and person-centered, culturally responsive care. Despite these advancements, the role of educators particularly in facilitating reflective debriefing remains critical to ensuring meaningful learning. Future research should focus on the ethical standardization of AI integration and the evaluation of long-term impacts on clinical performance and patient safety.

Keywords: Pregnancy Simulator; Midwifery Education; Artificial Intelligence; Virtual Reality; Person-Centered Care.

Introduction (Pendahuluan)

Midwifery and maternity nursing education require mastery of complex clinical skills alongside the ability to make rapid, high-stakes decisions in maternal and neonatal emergencies.¹ A persistent challenge for educational institutions is students' limited exposure to diverse real-world clinical scenarios, particularly high-risk cases that are relatively rare yet potentially life-threatening.² In response, simulation has become a core component of health professions education, bridging the gap between classroom theory and clinical practice.³ Simulation provides a controlled, safe environment in which students can practice without posing risk to patients.

Historically, the development of pregnancy simulators has focused primarily on physical fidelity—that is, the extent to which a manikin replicates human anatomy and the accuracy with which embedded sensors respond to clinical interventions.⁴ However, recent advances, particularly the integration of Generative Artificial Intelligence (AI) indicate a fundamental paradigm shift.⁵ As highlighted by McGrew et al. (2024), simulators are increasingly conceptualized not merely as tools for psychomotor skill acquisition but as interactive platforms that support the development of person-centered care.⁶ These technologies enable learners to engage in dynamic, empathetic interactions, extending the focus beyond procedural competence to include respect for patient dignity, preferences, and individual values within the healthcare context.

A further limitation of traditional midwifery education lies in the difficulty of providing clinical exposure that reflects diverse social, ethnic, and cultural backgrounds especially in regions with relatively homogeneous populations.⁷ Generative AI- and telehealth-based simulators offer a potential solution by enabling the creation of virtual patients with

varied cultural identities.⁶ This development underscores the growing importance of cultural responsiveness, wherein simulation is used to train students to recognize implicit biases and adapt communication strategies to patients' cultural contexts. In this capacity, simulation serves not only as a pedagogical tool but also as a mechanism to address health disparities by preparing practitioners who are more responsive to the social determinants of health.

Culturally responsive simulation, students are provided with a safe space to make communication errors without the risk of offending or harming real patients.⁸ This redefines the simulator's role from a mere skill-testing device to a medium for reflective practice.⁹ Students learn not only what to do clinically (e.g., managing obstetric hemorrhage) but also how to communicate interventions in ways that respect patient autonomy and respond to emotional and cultural needs.

To date, much of the literature has focused on the effectiveness of traditional high-fidelity manikin-based simulation. In recent years, however, there has been an explosion of educational technology innovations reshaping maternity simulation. Gamel et al., (2022) has progressed from simple physical devices simulating the physical burden of pregnancy¹⁰, to immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR)^{11,12}, and further toward the integration of Generative AI in telehealth-based simulations⁶. However, existing reviews remain fragmented and predominantly focus on single modalities or outcomes, lacking a comprehensive mapping of technological evolution alongside shifts in pedagogical orientation. Despite these advances, there remains a lack of comprehensive synthesis mapping the evolution of these tools and the corresponding shift in pedagogical focus—from fostering empathy to developing advanced clinical and cognitive competencies. A scoping review is therefore warranted to consolidate current evidence and inform educators in selecting

technologies aligned with specific learning objectives.

A scoping review approach was selected because simulation technology in midwifery education is multidisciplinary, expansive, and rapidly evolving. Unlike a systematic review, which typically addresses a narrowly defined question regarding the effectiveness of a single intervention, a scoping review enables researchers to map the breadth of existing literature, identify various types of technologies employed (ranging from manikins to AI-driven systems), and detect research gaps in primary studies.¹³ This approach is particularly appropriate for providing a comprehensive overview of the current state of this dynamic field.

The objective of this scoping review is to identify and map contemporary trends in the use of pregnancy simulation tools in midwifery and maternity nursing education. Specifically, the review seeks to answer the following question: How have pregnancy simulation tools evolved and been implemented within midwifery and maternity nursing curricula over the past decade?

Methods

(Metode Penelitian)

This study employed a qualitative approach using a scoping review methodology guided by the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) framework to ensure methodological rigor and transparency¹⁴⁻¹⁶. The framework originally proposed by Arksey and O'Malley and subsequently refined by Levac et al. (2010) was followed systematically. This approach was selected because it is particularly suitable for examining emerging fields, with the aim of identifying the breadth of evidence, types of approaches, and existing research gaps in the literature on pregnancy simulation tools.

Stage 1: Identifying the Research Questions

The primary and subsidiary research questions were formulated as follows:

RQ1: What types of pregnancy simulation tools are currently used in midwifery and nursing education?

RQ2: What learning objectives and competencies are targeted using pregnancy simulation tools?

Stage 2: Identifying Relevant Studies (Search Strategy)

Articles were retrieved within the publication period from 2015 to 2026, with the final search conducted on February 20, 2026. Only publications in English were included, comprising original research articles and review papers.

The search strategy employed a combination of the following keywords: ("pregnancy simulation" OR "pregnancy simulator" OR "maternity simulator" OR "maternity model" OR "simulated pregnancy" OR "obstetric simulator") AND ("midwifery education" OR "nursing education" OR "health professions education" OR "clinical education" OR "simulation-based learning").

Records were identified from the following databases: Scopus (4 articles), PubMed (324 articles), Springer Nature Link (5 articles), ScienceDirect (22 articles), ERIC (71 articles), and Google Scholar (237 articles), yielding a total of 663 records. Titles and abstracts were screened, followed by full-text review based on the predefined inclusion criteria. To ensure quality, only peer-reviewed journal articles or book chapters available in full text were included. Results from Google Scholar were carefully screened to exclude non-academic sources. Two reviewers independently conducted the selection process, and discrepancies were resolved through discussion or consultation with a third reviewer.

Stage 3: Study Selection (Inclusion and Exclusion Criteria)

The selection process was conducted systematically to minimize the risk of selection bias. The screening protocol was developed in accordance with PRISMA-ScR guidelines¹⁶.

Inclusion criteria:

1. Studies addressing pregnancy simulation tools;
2. Conducted within the context of midwifery or nursing education;
3. Empirical studies, development studies, or evaluation studies;
4. Published between 2015 and 2026;
5. Written in English.

Exclusion criteria:

1. Studies focusing solely on childbirth simulators without a pregnancy simulation component;
2. Clinical interventions involving real pregnant patients;
3. Abstract-only publications without full text;
4. Editorials, opinion papers, or commentaries lacking a description of the simulation tool;
5. Studies with insufficient methodological description.

From the initial 663 records, duplicates were removed, and the remaining titles and abstracts were screened. Following full-text review, nine studies met all eligibility criteria and were included in the final analysis (see Figure 1). The final inclusion of nine studies reflects the application of stringent eligibility criteria, particularly the requirement for explicit focus on pregnancy simulation tools and sufficient methodological detail, which substantially limited the number of eligible studies.

Stage 4: Data Charting

Two reviewers independently charted data from each included study using predefined

components, including study methodology, classification of pregnancy simulation tools, and pedagogical orientation mapping. Contextual analysis was applied to clarify implicit or insufficiently detailed information in the source articles. Full texts were re-examined to ensure accuracy and consistency, and disagreements were resolved through consensus. The final dataset was compiled into table, summarizing simulator classifications and pedagogical orientations in midwifery and nursing education.

Stage 5: Collating, Summarizing, and Reporting the Results

Extracted data were collated, synthesized, and summarized to map the classification of pregnancy simulation tools according to function, technology, and educational purpose. Implementation challenges were analyzed thematically to identify patterns and variations across studies. Initial coding was conducted by one researcher and independently validated by a second researcher; discrepancies were resolved through consensus. Final themes were summarized in tabular form to facilitate cross-study comparison and to highlight factors influencing the effectiveness, adoption, and scalability of pregnancy simulation tools.

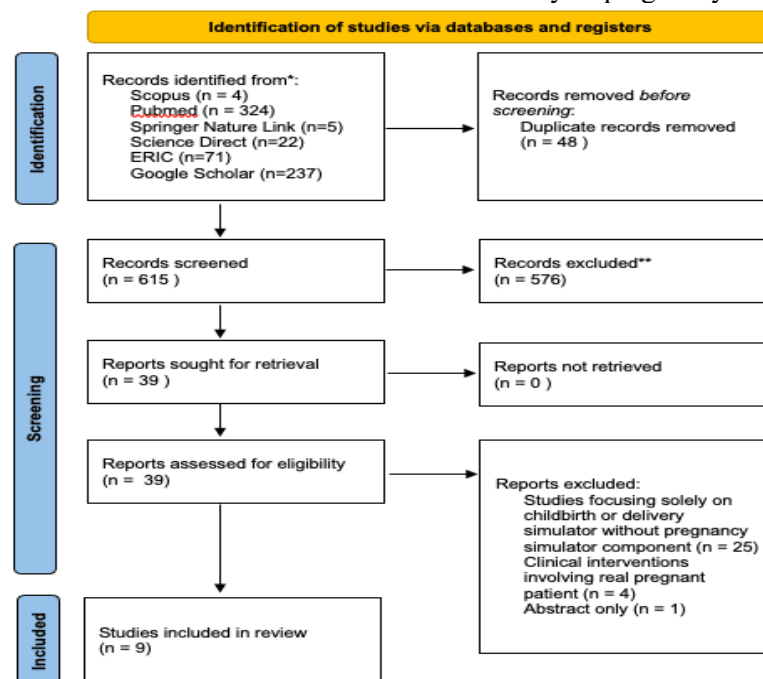


Figure 1. PRISMA Flow Diagram for Study Selection

Results and Discussion (Hasil dan Pembahasan)

Methodological quality of the included studies was assessed using the relevant critical appraisal checklist from the Joanna Briggs Institute (JBI), selected according to each study design. The checklist comprised eight criteria (Q1–Q8), with responses categorized as Y = Yes, U = Uncertain, and N = None. Overall, methodological quality was satisfactory. Table 1 demonstrates six of the nine studies met all appraisal criteria, indicating strong clarity in research design, data collection, and reporting. Two studies demonstrated minor methodological limitations, with one or more criteria rated as

Uncertain, primarily related to reporting transparency. One study showed greater variability, including one criterion rated as None and several rated as Uncertain, suggesting incomplete reporting in specific domains. Across studies, core methodological domains (Q1 and Q2) were consistently fulfilled. In contrast, Q6 exhibited the greatest variability, indicating a potential recurring weakness in methodological rigor or reporting across the evidence base. Consistent with scoping review methodology, no studies were excluded based on critical appraisal results; instead, appraisal findings were used to contextualize the interpretation of evidence during synthesis.

Table 1. Critical Appraisal of Includes Studies

No	Authors (Years)	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1.	Hall, S.W. (2015) ¹⁷	Y	Y	Y	Y	Y	Y	Y	Y
2.	Hernon et al., (2023) ¹⁸	Y	Y	U	U	U	N	U	Y
3.	Gamel et al. (2022) ¹⁰	Y	Y	Y	Y	Y	Y	Y	Y
4.	Cobbett and Clarke (2016) ¹⁹	Y	Y	Y	Y	Y	Y	Y	Y
5.	Chang et al., (2024) ¹²	Y	Y	Y	Y	Y	Y	Y	Y
6.	Brown and Tortorella (2020) ²⁰	Y	Y	Y	Y	Y	U	Y	Y
7.	McGrew et al., (2024) ⁶	Y	Y	Y	Y	U	N	Y	Y
8.	Silmi and Susanti (2025) ¹³	Y	Y	Y	Y	Y	Y	Y	Y
9.	Vogel et al., (2024) ¹¹	Y	Y	Y	Y	Y	Y	Y	Y

Table 2 demonstrates a clear technological evolution in maternity simulation across nine international studies conducted in North America, Europe, Asia, and the Middle East. Early implementations were dominated by high-fidelity manikins and traditional laboratory-based simulations (e.g., experimental comparative designs in the United States and Canada). These models emphasized psychomotor skill acquisition and controlled performance assessment within structured lab environments. Subsequent developments introduced wearable simulators (e.g., empathy-based pregnancy suits) that shifted the pedagogical focus toward embodied learning and affective domain outcomes, particularly empathy and experiential understanding of pregnancy-related physical

discomfort. This transition reflects an expansion from purely skills-based simulation to psychosocial and attitudinal objectives. More recent studies illustrate a pronounced digital transformation, integrating Virtual Reality (VR), Augmented Reality (AR), AI-driven virtual patients, and machine learning–based platforms. These technologies enable immersive, situated, and adaptive learning environments, moving beyond static physical simulators toward interactive, scalable, and data-responsive systems. Hybrid approaches combining standardized patients, wearable devices, and digital overlays further demonstrate convergence between physical fidelity and virtual augmentation

Table 2. Characteristics of Included Studies

No	Author (Year)	Country	Discipline	Study Design	Participant Level	Educational Setting	Type of Simulator
1.	Hall, Susan W. (2015)	United States (North Carolina)	Nursing (Maternity Nursing Education)	Experimental (Retrospective Comparative Quantitative Study)	Undergraduate	Lab + Clinical (Hybrid setting)	Manikin (High-Fidelity Simulator)
2.	Hernon et al., (2023)	Ireland (International evidence synthesis)	Nursing & Midwifery Education	Qualitative — State-of-the-art Literature Review	Undergraduate (dominant) + Postgraduate/ Professional	Lab + Classroom + Clinical (Mixed setting)	Hybrid (Multiple technologies) include simulation manikins, video learning, virtual reality, and digital learning environments → a combination of physical & digital.
3.	Gamel et al. (2022)	Egypt	Midwifery Nursing	Experimental (Quasi-experimental research design)	Undergraduate	Lab/ Classroom	Wearable (Using Empathy Belly™ Pregnancy Simulator)
4.	Cobbett and Clarke (2016)	Canada	Maternal-newborn Nursing	Experimental (Randomized pretest-post-test control group design)	Undergraduate	Lab/ Classroom	Manikin (for face-to-face groups) and Virtual (vSim® for virtual groups)
5.	Chang et al., (2024)	Taiwan	Midwifery / Nursing	Experimental (Quasi-experimental design with experimental and control groups).	Undergraduate	Lab/ Classroom	Virtual Reality (MVR-SLS - Maternity VR-based Situated Learning System)
6.	Brown and Tortorella (2020)	Finland	Multi-disciplinary Health Care (covering Nursing, Medicine, and Midwifery)	Systematic Literature Review	Undergraduate & Professional	Lab + Clinical	Hybrid (Combination of Standardized Patient or human actor with Wearable technology or partial manikin)
7.	McGrew et al., (2024)	United States	Midwifery	Experimental (Pilot study of educational innovation with descriptive survey evaluation).	Graduate/ Professional	Lab + Classroom	Virtual / Artificial Intelligence (Using the generative AI platform "Enoserv" with virtual patients).
8.	Silmi and Susanti (2025)	Indonesia	Midwifery	Scoping Review (Using the Arksey and O'Malley framework and PRISMA-ScR guidelines)	Undergraduate & Professional	Lab + Classroom + Clinical	Software-based / Virtual (Focus on AI methods such as Machine Learning, Generative AI/ChatGPT, and AI-powered simulations)
9.	Vogel et al., (2024)	Germany	Midwifery	Experimental (Prospective observational study with pre-test and post-test design)	Undergraduate	Lab	Wearable / Hybrid (Using Microsoft HoloLens 2 AR glasses combined with a manikin)

Table 3 classifies the included studies according to simulator category, fidelity level, development status, interaction type, and primary educational purpose. Across all studies, interactive simulation was consistently implemented, indicating a strong pedagogical preference for active, experiential learning approaches in maternity education. A dominant pattern is the prevalence of high-fidelity simulation, whether delivered through traditional manikins, wearable devices, virtual reality (VR), augmented reality (AR), artificial intelligence (AI)-driven virtual patients, or hybrid configurations. Early implementations primarily relied on commercial high-fidelity manikins focused on psychomotor skill acquisition and clinical performance evaluation. Subsequently, wearable simulators emerged with an expanded

objective, shifting beyond technical skill training toward empathy development and attitudinal transformation. This marked a pedagogical broadening from performance-based outcomes to affective domain integration. More recent innovations demonstrate a transition toward intelligent and immersive systems, including VR-based situated learning, AR-enhanced manikins, and AI-powered virtual patients. These technologies provide high cognitive and situational fidelity, enabling dynamic decision-making practice, telehealth communication training, predictive analytics, and adaptive feedback mechanisms. Notably, several advanced systems remain research prototypes, indicating ongoing technological maturation and experimentation within the field.

Table 3. Classification of Pregnancy Simulation Tools

No	Study	Simulator Category	Fidelity Level	Commercial / Prototype	Physical Interaction	Main Purpose
1.	Hall, Susan W. (2015)	Manikin (High-Fidelity Simulator)	High Fidelity	Commercial	Interactive	The primary goal is to improve practical learning and critical thinking; outcomes are measured through ATI scores and predicted NCLEX performance as a form of learning evaluation.
2.	Hernon et al., (2023)	Hybrid (Multiple technologies) include simulation manikins, video learning, virtual reality, and digital learning environments → a combination of physical & digital.	Medium – High Fidelity (dominant)	Commercial (majorities)	Interactive	The primary objective of the review was the use of technology for teaching and assessing clinical psychomotor skills. Many studies measured students' clinical skills performance, competency, and evaluation.
3.	Gamel et al. (2022)	Wearable (Using Empathy Belly™ Pregnancy Simulator)	High fidelity	Commercial	Interactive	The main objective is to increase students' empathy, understanding and positive attitudes towards the physical difficulties experienced by pregnant women.
4.	Cobbett and Clarke (2016)	Manikin (for face-to-face groups) and Virtual (vSim® for virtual groups)	High-fidelity	Commercial	Interactive	The goal is to increase students' knowledge, confidence, and reduce anxiety in clinical decision making.
5.	Chang et al., (2024)	Virtual Reality (MVR-SLS - Maternity VR-based Situated Learning System)	High-fidelity	Prototype / Research	Interactive	Improve learning performance, problem-solving abilities, learning engagement, and clinical skills through OSCEs

No	Study	Simulator Category	Fidelity Level	Commercial / Prototype	Physical Interaction	Main Purpose
6.	Brown and Tortorella (2020)	Hybrid (Combination of Standardized Patient or human actor with Wearable technology or partial manikin)	High-fidelity	Mixed (Reviewing the use of commercial tools as well as research prototypes developed for hybrid simulation)	Interactive	(The main goal is to improve the Empathy & Skill of caregivers and interactions between caregivers and patients, communication, and clinical skills in a realistic context.
7.	McGrew et al., (2024)	Virtual / Artificial Intelligence (Using the generative AI platform "Enoserv" with virtual patients).).	High (High cognitive and situational fidelity through dynamic AI responses that mimic human interactions in telehealth scenarios)	Commercial	Interactive	(Training Skill and Empathy skills through telehealth communication, person-centered care, and cultural responsiveness)
8.	Silmi and Susanti (2025)	Software-based / Virtual (Focus on AI methods such as Machine Learning, Generative AI/ChatGPT, and AI-powered simulations)	High Fidelity (AI methods such as intelligent simulation and DSS provide high cognitive and situational fidelity for clinical decision making)	Mixed (Discusses commercial tools such as ChatGPT as well as research-based decision support system/DSS prototypes)	Interactive	Primary objectives include risk predictive analytics, decision support systems, and enhancing critical thinking skills.
9.	Vogel et al., (2024)	Wearable / Hybrid (Using Microsoft HoloLens 2 AR glasses combined with a manikin)	High fidelity (AR technology provides high visual fidelity by projecting realistic avatars onto physical manikins).	Prototype / Research (Using an AR simulation application called "Lumi" which was developed specifically for this educational and research purpose).	Interactive	Improve perception of knowledge, confidence, and skills in managing critical incidents

Table 4 delineates the classification of pregnancy simulation tools according to their technical functions and pedagogical orientations. The findings indicate a substantial technological evolution, which can be categorized into four principal groups: (1) Wearable and Physical Simulators focused on embodied empathy; (2) High-Fidelity Manikins designed for procedural clinical skills training; (3) Immersive Technologies (VR/AR) supporting situated learning; and (4) Generative AI and Telehealth systems aimed at enhancing clinical decision-making.

From a pedagogical perspective, a clear shift in orientation is evident. Whereas traditional simulators primarily emphasized empathy development and affective learning outcomes, contemporary technologies are increasingly directed toward mastery of critical incident management, person-centered care, and cultural responsiveness. These findings demonstrate that modern simulation tools function as holistic instruments, integrating technical proficiency with advanced interpersonal communication competencies.

Table 4. Thematic Summary of Pregnancy Simulation Tools

No	Theme	Sub-Theme
1	Evolution of Pregnancy Simulator Technology	a. Analog & Physical (Wearable) Phase: (Gamel et al., 2022) b. High-Fidelity & Hybrid Phase: (Hall, 2015; Brown & Tortorella, 2020). c. Immersive Phase (VR & AR): (Chang et al., 2024; Vogel et al., 2024). d. Artificial Intelligence Phase (Generative AI & Telehealth): (McGrew et al., 2024; Silmi & Susanti, 2025).
2	Pedagogical Orientation Shift (Empathy → Competency)	a. Foundations of Empathy and Attitude: (Gamel et al., 2022). b. Transition to Self-Confidence and Anxiety Reduction: (Cobbett & Snelgrove-Clarke, 2016). c. Mastery of Psychomotor and Clinical Skills: (Hernon et al., 2023; Chang et al., 2024). d. Critical Incident Competence and Cultural Responsiveness: (Vogel et al., 2024; McGrew et al., 2024).

Main Outcome: Evolution of Pregnancy Simulator Technology

1. Analog & Physical (Wearable) Phase
In the early stages, technology focused on physical simulations such as the Empathy Belly™¹⁰. These devices were mechanical, intended to provide realistic physical loading to address the mobility challenges of pregnant women.
2. High-Fidelity & Hybrid Phase
Continued evolution with the use of high-fidelity manikins that could emit sounds, measure fetal heart rates, and respond to medical interventions ¹⁷. A hybrid approach then emerged, combining human actors (standardized patients) with wearable technology to simultaneously create social and technical realism ²⁰.
3. Immersive Phase (VR & AR)
Technology evolved into the virtual realm. Virtual Reality (VR) creates a "situated" delivery environment ¹², while Augmented Reality (AR) allows students to view digital anatomical projections on top of physical manikins ¹¹. This addresses the limited space constraints of physical laboratories.
4. Artificial Intelligence Phase (Generative AI & Telehealth)
The current phase involves generative AI, which enables dynamic, two-way communication simulations. Simulations are no longer limited to physical procedures, but also encompass remote

interactions (telehealth) where virtual patients can respond uniquely based on student input ^{6,13}.

Secondary outcome: Pedagogical Orientation Shift

1. Foundations of Empathy and Attitude
In early literature, simulations (such as pregnancy simulators) were used as tools to foster empathy. The focus was on students understanding the physical burden of patients and thus developing a more positive attitude ¹⁰.
2. Transition to Self-Confidence and Anxiety Reduction
As virtual and in-person simulations evolved, the focus shifted to psychological preparedness. Simulations were used to build self-efficacy and reduce students' anxiety before encountering real patients in the hospital ¹⁹.
3. Mastery of Psychomotor and Clinical Skills
Technology began to be used specifically to teach complex technical skills (psychomotor skills). The use of the Objective Structured Clinical Examination (OSCE) in VR environments demonstrated that simulation is now a standard objective assessment of clinical competency ^{12,18}.
4. Critical Incident Competence and Cultural Responsiveness

Recent pedagogical orientations culminate in the management of critical incidents that are difficult to encounter in the practice setting¹¹. Furthermore, AI simulations are geared toward developing high-level competencies in culturally sensitive and person-centered care, ensuring students are professionally prepared for diverse healthcare environments⁶.

This scoping review successfully mapped the evolution and contemporary trends of pregnancy simulation tools in midwifery and maternity nursing education (RQ1) and identified the accompanying shift in instructional objectives (RQ2). The principal finding indicates that simulation technology has transformed from static physical teaching aids into intelligent and interactive digital ecosystems.

Technological Evolution: From Physical Simulation to Intelligent Digital Ecosystems

The findings demonstrate that pregnancy simulation technology have followed a clear evolutionary trajectory, transitioning from passive, physically oriented modalities toward active and immersive digital environments. In their early development, wearable simulators emphasized physical sensory stimulation to foster student empathy through mechanical restriction¹⁰. However, the limitations of physical devices in replicating complex pathophysiological dynamics prompted a shift toward High-Fidelity Simulation (HFS), which prioritizes clinical realism¹⁷. Advanced manikins enabled the externalization of theoretical knowledge into measurable psychomotor performance, particularly in managing obstetric emergencies that are rarely encountered in clinical placements yet carry high fatality risks.

This development was subsequently expanded through immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR)^{11,12}, which effectively transcend laboratory constraints by providing anatomically precise visualization and highly contextualized situational scenarios. The current frontier of innovation is marked by the integration of Generative Artificial Intelligence (AI),

fundamentally redefining simulation from a model of procedural rehearsal to one of cognitive–social interaction training. Unlike conventional simulators, generative AI facilitates dynamic, telehealth-based interactions in which virtual patients produce adaptive, unpredictable, and culturally nuanced responses^{6,13}. Analytically, this shift suggests that simulation fidelity has extended beyond anatomical realism toward “interpersonal fidelity,” facilitating the simultaneous mastery of both technical and interpersonal competencies within a more intelligent and inclusive learning ecosystem.

Pedagogical Shift: Reconstructing Competence in the Digital Era

Parallel to technological advancement, a fundamental shift in pedagogical orientation has emerged in midwifery and maternity nursing education. This transformation reflects a move from approaches centered on primary affective awareness toward strengthening multidimensional technical and psychological capacities. Whereas simulation was previously positioned as a tool for cultivating empathy through exposure to the physical burden of pregnancy, contemporary paradigms conceptualize simulation as a strategy for psychological risk mitigation. Through advanced simulation tools, students are provided with a psychologically safe environment to develop self-efficacy and deconstruct clinical anxiety, particularly in the management of critical incidents¹¹. Analytically, this shift indicates that simulation is no longer intended merely to help students “understand” emotionally, but to ensure they are operationally prepared to act decisively under pressure.

Moreover, the pedagogical orientation of modern simulation extends beyond psychomotor proficiency toward deeper humanistic competencies, particularly Person-Centered Care and Cultural Responsiveness. The integration of generative AI allows students to cultivate cultural sensitivity within adaptive virtual environments⁶. This evolution reflects curricular maturation, wherein competence is no longer perceived as a checklist of technical tasks but as the capacity to deliver care that respects patient autonomy and

sociocultural context. Accordingly, simulators are no longer merely instructional devices; they function as instruments for developing practitioners who are clinically competent, psychologically resilient, and ethically grounded in delivering culturally responsive care.

The Evolving Role of Educators in Technology-Enhanced Simulation

Amid the rapid technological revolution in simulation, the findings affirm that the role of midwifery educators is not diminished but transformed from information transmitters to facilitators and architects of learning experiences. The integration of advanced tools such as generative AI and immersive technologies requires educators to possess robust digital literacy in order to design scenarios that are not only clinically accurate but also psychologically safe⁶. Educators play a pivotal role in the debriefing phase, a critical component of simulation which, according to the principles of Debriefing for Meaningful Learning, is where deep reflection occurs²¹. In the digital era, educators serve as mediators between students and machines, ensuring that feedback generated by AI or simulators is translated into ethical and humanistic clinical understanding.

Furthermore, educators act as custodians of ethical and empathic dimensions that may not be fully captured in algorithm-driven interactions. When simulators are used to train Person-Centered Care and Cultural Responsiveness, educators must guide students in recognizing the nuanced human elements that technology cannot entirely replicate¹³. In this regard, educators function as a moral compass, ensuring that technological sophistication remains anchored in the foundational values of midwifery: compassionate, patient-centered, and safety-oriented care. Consequently, the successful implementation of emerging simulation technologies depends substantially on educators' readiness to integrate them into curricula in ways that promote critical thinking rather than mere procedural repetition.

Implications for Practice and Education

The findings have important implications for midwifery and maternity nursing education in the context of rapidly evolving simulation

technologies. First, the shift toward digitally enhanced and AI-integrated simulation necessitates strategic curriculum alignment. Rather than adopting technologies ad hoc, programs should match specific tools to defined learning outcomes. High-fidelity manikins remain essential for psychomotor skill development, whereas immersive and AI-based simulations are better suited for clinical reasoning, communication, and cultural responsiveness. Such alignment helps prevent technological determinism, where adoption is driven by novelty rather than pedagogical value. Second, the emergence of interpersonal fidelity alongside physical fidelity calls for a redefinition of competency frameworks. Competence should be understood as an integration of technical, cognitive, and relational abilities. Accordingly, assessment strategies must evolve to capture these multidimensional outcomes, incorporating performance-based, reflective, and communication-focused evaluations, such as structured debriefing and scenario-based assessment. Third, the integration of advanced technologies highlights the need for faculty development in digital pedagogy. Educators require not only technical proficiency but also the ability to design effective simulation scenarios and facilitate high-quality debriefing. Without this capacity, technologies risk being underutilized or misaligned with learning objectives. Continuous professional development in instructional design, digital literacy, and simulation facilitation is therefore essential. Fourth, simulation offers a scalable approach to strengthening cultural competence and equity in training. AI-driven virtual patients can expose students to diverse sociocultural contexts not readily available in clinical settings. However, careful scenario design is necessary to mitigate the risk of reinforcing algorithmic bias or cultural stereotypes. Fifth, implementation must consider infrastructure, cost, and scalability. Although immersive and AI-based systems provide significant pedagogical benefits, they may be resource-intensive. Hybrid models that integrate low-cost physical simulators with digital augmentation offer a pragmatic and scalable alternative, particularly in low-resource settings. Finally, a human-centered approach remains essential. Despite increasing technological

sophistication, simulation must remain grounded in the core values of midwifery, compassion, respect, and patient-centered care. Educators play a critical role in ensuring that technology enhances, rather than replaces, the relational dimensions of care. Effective integration therefore requires balancing innovation with pedagogical and ethical considerations.

Despite offering a comprehensive overview of current trends, several limitations must be acknowledged. First, database and language limitations: although major databases such as PubMed and Scopus were utilized, relevant articles published in languages other than English and Indonesian may not have been captured. Additionally, limited grey literature searching may have resulted in the underrepresentation of locally developed prototype innovations. Second, the recency of the time frame: inclusion of literature up to 2026 (including early-access articles) provides a highly current perspective; however, technologies such as generative AI in midwifery remain largely in pilot phases, and evidence regarding long-term clinical effectiveness remains limited.⁶ Third, methodological heterogeneity: the included studies ranged from descriptive innovation reports to randomized controlled trials (RCTs), limiting the feasibility of statistical comparison and necessitating primarily narrative and thematic synthesis. Fourth, potential selection bias: although screening was conducted independently by two reviewers, interpretations of “fidelity” and “pedagogical orientation” were qualitative and may have been influenced by researcher perspective.

Conclusion (Simpulan)

This review concludes that pregnancy simulation technology has evolved from simple physical teaching aids into sophisticated digital ecosystems encompassing high-fidelity manikins, Virtual and Augmented Reality (VR/AR), and Generative Artificial Intelligence (AI). This technological transformation addresses the demands of modern education for safe and adaptive learning environments, enabling students to practice procedural clinical skills alongside dynamic cognitive interactions within telehealth scenarios. Intelligent simulation

systems demonstrate the capacity to replicate both medical complexity and sociocultural diversity that are often difficult to encounter in traditional clinical settings.

Pedagogically, a clear shift has occurred from fostering embodied empathy alone toward the development of holistic competence emphasizing Person-Centered Care and Cultural Responsiveness. These findings imply that educational institutions must update curricula and strengthen faculty capacity as facilitators in the digital era to preserve the reflective depth of simulation-based learning. A critical next step involves establishing ethical standards for AI utilization and conducting longitudinal research to ensure that competence acquired in simulated environments translates into improved patient safety and quality of care in real-world practice.

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(Daftar Pustaka)

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