# Effect of Implementing Artificial Intelligence-Based Holographic Learning on Nursing Students' Competence in Leopold's Maneuvers

**Asmaa Anwar Abd el-glil [(1)], Doaa Mohamed Reda [(2)], Mohamed Samir Hassan [(3)], Lawahez Mabrouk Dwedar [(4)]**

(1,4) Assistant Professor of Obstetrics and Gynecological Health Nursing, Faculty of Nursing, Kafrelsheikh University, Egypt.
(2) Lecturer in Maternal and Newborn health nursing, Faculty of Nursing, Cairo university
(3) MSc Information and Technology, Faculty of Computers and Artificial Intelligence, Helwan University, Egypt
***Corresponding author***: Lawahez_mabrouk2014@nur.kfs.edu.eg

## Abstract

**Background:** Traditional obstetric training often limits students' opportunities to practice clinical skills such as Leopold maneuvers due to insufficient patient exposure and inconsistent supervision. Emerging technologies such as Artificial Intelligence (AI) and holographic learning offer immersive, interactive, and adaptive platforms that may enhance students' knowledge, psychomotor skills, and confidence. **Aim:** This study aimed to evaluate effect of implementing Artificial Intelligence-Based Holographic Learning on Nursing Students' Competence in Leopold's Maneuvers. **Design:** A quasi-experimental post-test-only design was conducted with 130 nursing students at Kafrelsheikh University. Students were divided into two groups: a study group (n = 65) trained using AI-based holographic learning and a control group (n = 65) trained conventionally. Data was collected using a structured interviewing questionnaire, an observational checklist for Leopold's maneuvers, Nursing student's self-confidence questionnaire, and Nursing student's satisfaction questionnaire. **Results:** Students in the AI-based holographic group achieved significantly higher scores in knowledge (Mean ±SD = 20.2 ± 5.7 vs. 17.1 ± 5.2, p = 0.002), practice (Mean ±SD = 41.7 ± 13.1 vs. 34.1 ± 14.2, p = 0.002), and self-confidence (Mean ±SD = 11.9 ± 3.4 vs. 8.0 ± 2.4, p < 0.001). Satisfaction was also significantly higher (Mean ±SD = 15.1 ± 5.1 vs. 12.1 ± 5.9, p = 0.002). **Conclusion:** AI-based holographic learning proved more effective than traditional methods in enhancing knowledge, clinical competence, confidence, and satisfaction regarding Leopold's maneuvers. **Recommendations:** AI-based holographic learning should be incorporated into midwifery programs as an adjunct to conventional instruction.

**Keywords:** Artificial intelligence, Holographic Learning, Leopold's Maneuvers, Nursing Students' Competence

## Introduction

Traditional learning in medical and nursing education has long relied on didactic lectures, teacher-centered instruction, and rote memorization, where students act as passive recipients of information rather than active participants. The delivery of knowledge is usually one-directional, from instructor to learners, through lectures, textbooks, and limited demonstrations. Methods typically include classroom-based teaching, note-taking, and written

examinations, with minimal integration of interactive or practical components **(Elmarash, Adrah, & Eljadi, 2021).**

Innovation in nursing education has become essential to meet the growing complexity of healthcare and the need for competent, practice-ready graduates. Innovative learning strategies incorporate advanced technologies, learner-centered approaches, and evidence-based pedagogies that go beyond traditional lecture-based teaching. Methods such as simulation-based education, virtual and augmented reality, holographic learning, and AI-driven adaptive platforms provide immersive, interactive, and safe environments for skill acquisition **(Li, Xu, & Chen, 2023).**

Holography has emerged as a valuable complement to AI in medical education. By generating three-dimensional, realistic, and interactive models, holographic learning provides students with immersive experiences that enhance spatial perception and procedural accuracy. This interactive environment fosters engagement and allows learners to repeatedly practice essential techniques, such as Leopold maneuvers, without the limitations of mannequin-based or patient-dependent training **(Brown et al., 2022; Li, Xu, & Chen, 2023).**

When combined, Artificial intelligence (AI) and holography create intelligent holographic learning platforms that replicate authentic clinical environments. This hybrid approach supports individualized, immersive, and skill-based training, enabling students to refine their psychomotor abilities while receiving adaptive guidance. Such integration addresses the persistent challenge of bridging theoretical knowledge with hands-on practice in obstetrics and nursing education **(Ahmed, Ali, & Elshaer, 2022; Mousa, Khalaf, & Younes, 2023).**

Holographic learning, especially when integrated with artificial intelligence, offers an innovative solution by creating immersive, three-dimensional, and interactive training environments that closely replicate real clinical scenarios **(Li, Xu, & Chen, 2023).** This technology allows repeated, risk-free practice, personalized feedback, and standardized skill assessment, thereby bridge the gap between theoretical knowledge and clinical application. Investigating the effectiveness of AI-driven holography in nursing education is therefore essential to provide evidence-based strategies that enhance students' competence, satisfaction, and preparedness for professional practice **(Ahmed, Ali, & Elshaer, 2022; Mousa, Khalaf, & Younes, 2023).**

Leopold's maneuvers remain a cornerstone of obstetric assessment, critical for determining fetal position, presentation, and engagement. However, many nursing students struggle to acquire competence in these skills due to inconsistent supervision and limited clinical exposure. Insufficient practice opportunities often result in reduced confidence and preparedness for real-world patient care, emphasizing the urgent need for advanced, technology-supported training strategies **(Bukhari et**

**al., 2020; Koh, Lee, & Teo, 2021; Shimizu et al., 2021).**

Despite growing research on virtual reality and AI in clinical education, limited evidence exists on the combined effect of AI-driven holographic learning for specific obstetric skills such as Leopold's maneuvers. This study therefore aims to evaluate the effect of implementing Artificial Intelligence-Based Holographic Learning on Nursing Students' competence in Leopold's Maneuvers. By addressing gaps in knowledge and practice, the findings are expected to contribute to curriculum innovation and enhance clinical training outcomes in obstetric nursing **(Ahmed, Ali, & Elshaer, 2022; Saied et al., 2025).**

Obstetrics and gynecological nursing students could teach how to use holographic technology to build abilities including clinical reasoning and patient assessment. They are in charge of instructing themselves on how to engage with and decipher holographic scenarios, making sure the technology is utilized efficiently to offer a secure and authentic learning environment that enhances conventional teaching techniques **(Ditzel & Collins,. 2021).**

## Significant of the study

The persistent challenges nursing and midwifery students face in acquiring competence in Leopold's maneuvers. Clinical exposure during obstetric training is often limited due to ethical concerns, patient safety, and the availability of suitable cases, leaving students with insufficient opportunities to practice these essential skills **(Shimizu, Tanaka, & Yamada, 2021).** As a result, many graduates report low confidence and inadequate psychomotor ability in abdominal palpation and fetal assessment, which are critical for ensuring safe maternal and neonatal outcomes **(Koh, Lee, & Teo, 2021).**

Artificial intelligence AI provides powerful tools to enhance clinical education through personalized learning environments, predictive analytics, and real-time feedback mechanisms. These systems allow educators to dynamically tailor instruction based on learners' performance and identify knowledge or skill gaps. Such capabilities significantly improve procedural competence, especially in complex clinical tasks, and have been increasingly integrated into healthcare training to ensure standardized and equitable assessment **(Chan et al., 2024; Zhao, Hu, & Wang, 2023).**

The significance of this study lies in addressing one of the critical gaps in nursing education, ensuring adequate and standardized clinical training opportunities for obstetric procedures such as Leopold's maneuvers. Traditional approaches often limit students' exposure to real patients, resulting in insufficient practice, variable supervision, and decreased confidence in clinical decision-making **(Shimizu, Tanaka, & Yamada, 2021).**

Furthermore, the findings will contribute evidence-based recommendations for integrating AI-driven holography into nursing curricula, promoting equitable access to high-quality training resources, and ultimately

improving the quality of obstetric care **(Li, Xu, & Chen, 2023; Mousa, Khalaf, & Younes, 2023).** These findings reinforce the need to integrate holographic technologies into nursing curricula as a complement to traditional and simulation-based approaches.

## Aim of the study:

To evaluate effect of Implementing Artificial Intelligence-Based Holographic Learning on Nursing Students' Competence in Leopold's Maneuvers"

### Research hypotheses

**To reach the aim of this study, the following Null hypotheses were formulated**

H1: No statistically significant difference in mean score of Leopold's Maneuvers knowledge at posttest between students who receive AI-Based Holographic Learning and those who receive traditional methods.

H2: No statistically significant difference in mean score of nursing student's skills at posttest between students who receive AI-Based Holographic Learning and those who receive traditional methods.

H3: No statistically significant difference in mean score of nursing student's confidence at posttest between students who receive AI-Based Holographic Learning and those who receive traditional methods.

H4: No statistically significant difference in mean score of nursing student's satisfaction at posttest between students who receive AI-Based Holographic Learning and those who receive traditional methods.

### Operational definition

**Nursing Students' Competence in Leopold's Maneuvers:** in this study refers to knowledge, psychomotor skills, and confidence in performing the skills as measured by nursing students' knowledge questionnaire, observational checklist for leopold's maneuvers, nursing student's self-confidence questionnaire and nursing student's satisfaction questionnaire.

## Subject and Methods

### Research design:

A quasi-experimental design (nonequivalent control group design – after only) was adopted. A quasi-experimental design can be characterized as a type of research design that shares similarities with experimental research, albeit not meeting the criteria for true experimental research. The nonequivalent groups design, a form of between- subjects design, does not involve the random assignment of participants to different conditions. Within a Posttest only, the two dependent variables of Leopold's maneuvers knowledge, skills, confidence and satisfaction were assessed once subsequent to the implementation of AI-based holographic learning.

### Setting

The study is conducted at obstetric skills laboratory/ faculty of nursing/ kafer elsheikh University The laboratory is placed on the third floor at the Faculty of Nursing and opened practical hours

from 8am: 2pm. It comprises and it contains all the required equipment such as (hard surface, doll of Leopold's Maneuvers, manikins, sonicad) for the obstetric and gynecological clinical procedures except AI-Based Holographic Learning.

**Sample**

A convenient sample was used to recruit (130 nursing students). Those students were evenly distributed with a mix of male and female nursing students into two groups (study group "AI based holographic learning "=65 students and control "traditional training method "=65 students).

**Sample size calculation**

Based on data from literature ***(Yu Q, Li B & Wang Q (2022)*** considering level of significance of 5%, and power of study of 80%, the sample size can be calculated using the following formula:

$$n = \frac{2(Z\alpha/2 + Z\beta)\text{^}2 \times p\,(1-p)}{(d)\text{^}2}$$

Where, p = pooled proportion obtained from previous study; d = expected difference in proportion of events; $Z_{\alpha/2}$ =1.96 (for 5% level of significance) and $Z_{\beta}$ = 0.84 (for 80% power of study). Therefore,

$$n = \frac{2(1.96 + 0.84)^2 \times 0.727\,(1-0.727)}{(0.22)\text{^}2} = 64.3$$

Accordingly, the sample size required is 65 in each group.

**Tools for Data Collection**

Five tools were used for data collection: Tool I: A structured interviewing questionnaire, Tool II: Nursing students' knowledge questionnaire. Tool III: Observational checklist for Leopold's Maneuvers, Tool IV: Nursing student's self-confidence questionnaire and Tool V: Nursing student's satisfaction questionnaire.

**Tool (I): A structured interviewing questionnaire**:

It was developed by researchers following a review of pertinent literature. It consisted of**:**

**Personnel data of nursing students:** it comprised of 4 items which were (age, gender, residence, and attending any training courses about AI-Based Holographic Learning regarding Leopold Maneuver.

**Tool (II): Nursing students' knowledge questionnaire:** It was designed by researchers after reviewing related literature **Bukhari, S. et al. (2020).**, **Elmarash, G., Adrah, M., Eljadi, E., (2021)**. It was designed to measure nursing students' knowledge regarding Artificial Intelligence-Based Holographic Learning, Leopold Maneuver. It comprised of 2 parts; each section consisted of questions with total of 15-multiple-choice questions. For questionnaire was calculated for each item as follows: correct and the complete answer was scored (two points), incomplete answer was scored (one point), and the wrong answer was scored (zero points).

**Part one: General knowledge about AI-Based Holographic Learning** "7 question" (definition of AI-Based Holographic Learning, uses, advantages, disadvantages, how work,

characteristics, how can design simple Hologram).

**Part two: Knowledge regarding Leopold's Maneuvers** "8 question" (definition of Leopold's Maneuvers, indications and rationales for each grip, measurement of fundal height, lie of fetus, position of fetus, presentation of fetus, attitude of the fetus, engagement of fetus).

**Scoring system:** scores range from 0 – 60

**Poor knowledge**: scores that are lower than 30 (< 50%)

**Good knowledge**: scores between 30 – 39 (50% - 65%)

**Very good knowledge**: scores that are higher than 39 (> 65%)

**Tool (III): Observational checklist for Leopold's Maneuvers:** It was constructed by the researchers based on reviewing the related literatures **Koh, C. W., Lee, P. S., & Teo, M. H. Y. (2021).** It was used for assessing the nursing students' practices regarding Leopold's Maneuvers. It consisted of 29 steps divided into 7 sections as follows: Pre procedure tasks (9 steps). – fundal level measurements (2 steps). – fundal grip (2 steps). – bilateral grip (2 steps). – first pelvic grip (3 steps). – second pelvic grip (4 steps). – Auscultation and determine position (2 steps). -Post procedure tasks (5 steps).

**Scoring system:**

Each step assigned a score of (0) for not completed, (1) for incompletely completed, and (2) for completely completed.

**Scoring system: scores range from 0 – 58**, scores that are lower than 35 (< 60%) are **Unsatisfactory practices:** scores that are lower than 35 (< 60%)

**Satisfactory practices:** scores that are 35 or higher (60% or higher)

**Tool (IV): Nursing student's self-confidence questionnaire:** It was adopted from ***(Mohammed and Ahmed, 2016)*** to assess nursing students' self-confidence after implanting teaching and training methods regarding Leopoldp's Maneuvers. It composed of 7 items such as (I feel more confident about my skills, I am better able to assess pregnant woman, the training helped me to think critically, I feel better prepared to care situation for real, I feel more confident in my decision-making skills …etc.)

**Scoring system:**

Agree (2), undecided (1), and disagree (0) were the ratings assigned to each item on a three-point Likert scale each. The total score was determined by summing the scores of all elements. There is a potential score range of 0 to 14, with a higher score indicating greater self-confidence. Total score was categorized into:

**High self-confidence**: if score is (11-14).

**Moderate self-confidence**: if score is (6-10 score).

**Low self-confidence:** if score is (0-5 score).

**Tool (V): Nursing student's satisfaction questionnaire:** It was developed **by (Borim Nejad et al., 2015)** to evaluate factors like the extent to which one is enjoying or

invested in the subject matter and the practicality of newly acquired information and abilities; the assessment consists of eleven items, such as (Teaching methodology is enjoyable. I found this approach to be sufficient in satisfying my information requirements. My profession can benefit from the knowledge and skills that I have acquired through this approach. With the implementation of this methodology, my performance was enhanced, learning occurred more efficiently with this method …etc.)

**Scoring system:**

We will use a 3-point Likert scale for each item, (completely = 2, somewhat = 1, not at all = 0). A higher score indicated greater satisfaction on this questionnaire, which ranged from 0 to 22. The degree to which students will be satisfied with the method of instruction fell into three categories:

**High satisfaction**: if score is (17 - 22).

**Moderate satisfaction**: if score is (8–16).

**Low satisfaction**: if score is (0-7).

**Tool validity**

The content validity of the tool was tested and confirmed by three scholastic nursing specialists in the field of Obstetrics and Gynecological health nursing. The tools were validated for clarity, relevance, and completeness of its contents. Accordingly, the recommended modifications were performed.

**Tool reliability**

The reliability of the instruments that were used for the study was tested using Cronbach's alpha coefficient test.

| Tool | Cronbach's alpha value |
|---|---|
| Tool I: Nursing students' knowledge questionnaire. | 0.903 |
| Tool II: Observational clinical learning guide for Leopold Maneuver. | 0.897 |
| Tool III: Nursing student's self-confidence questionnaire. | 0.899 |
| Tool IV: Nursing student satisfaction questionnaire. | 0.896 |

**Pilot study**

A pilot study was conducted on 10% (13 nursing students) of the total sample size. The objective of the investigation was to assess the clarity, objectivity, feasibility, and applicability of the tools, as well as to identify any potential issues that may arise during data collection.

**Ethical consideration**

Before the study began, the Kafer el-shikh University research ethics committee was consulted (KFSIRB200-642) in 2024. To earn the trust and confidence of the nursing students, the researchers explained the purpose and significance of the study before administering the tools. The

researchers ensured confidentiality and obtained informed consent from nursing students before they participated in the study. Nursing students were not exposed to any psychological, social, or bodily harm as a result of participating in the study. Also, students were reassured that their data would only be utilized for research and would not impact their grades in any way, both now and in the future.

**Field work:**

After explaining the purpose of the research to the dean of the faculty of nursing at kafer el-sheikh University, we were able to get their written formal approval to proceed with the study. The research, which lasted for three months and began in middle of February 2025 and finished at the end of May 2025. Researchers met with obstetric nursing students three times a week, on Saturday, Monday, and Wednesday, from 9:00 a.m. to 2:00 p.m., rotating between groups. This was done in accordance with the students' academic schedules. There were four stages to the research process: **preparatory phase, interviewing phase, implementation phase and evaluation phase**

**Preparatory phase:**

- **Preparation of Study Tools:** Researchers combed in-depth examination through relevant local and international literature, the researchers formulated Tool I. Tools II, III, IV and V were adopted.
- **Preparations for a PowerPoint** which includes knowledge about AI-Based Holographic Learning & Leopold's Maneuvers procedure. The content was created to meet the above-mentioned objectives. We used artificial intelligence in preparing the booklet content as well as creating PowerPoint. An illustrative colorful booklet prepared as a guide for the study group. The booklets were distributed to students who participated in the study at the end of sessions.
- **Preparation of AI-Based Holographic Learning video:** Educational concepts were scripted and transformed into visual lessons. Adobe After Effects, videos were designed with animations and explanatory diagrams on a black background to enhance projection clarity. Steps of Leopold's Maneuvers video were arranged into a four-sided mirrored format (top, bottom, left, right) to generate the holographic effect when reflected on the pyramid. Then, Three-Dimensional (3D) Models relevant to the learning topics were created in Blender and 3D. The models were animated with rotation, highlighting, and zooming features. Final output was exported as holographic videos to arrange four mirrored perspectives. The steps of Leopold's Maneuvers and their technique that developed by specialized engineer under researcher's supervision.

- **Preparation of Holographic Display Setup**: The researchers developed holographic display through specialized engineer and conducting assessment thorough relevant and recent research: https://youtu.be/7YWTtCsvgvg?si=qyt3gIF_-xrBS2ya. A standard smartphone (minimum 6-inch screen). A pyramid-shaped structure made of transparent acrylic/plastic sheets, positioned on top of the smartphone. Projection Technique: Each side of the pyramid reflected a mirrored video, creating a floating 3D hologram visible from different angles.
- **Interviewing phase:** The researchers began the interview by introducing themselves to each nursing student, welcoming them, explaining the purpose of the study, giving them all the information they needed to follow the interventions, and finally, getting their signed consent to participate. All nursing students first assessed for personal data using the structured interviewing questionnaire (Tool: I). It will take about 5 minutes on average for participants to finish the survey.

**Implementation phase**

Nursing students were assigned into two equal groups: the control group (65 nursing students) and the AI based holographic learning group (65 women). To exclude the potential for sample contamination, the study was started with the control group and finished before the AI based holographic learning group.

**For control group:** traditional training method was used for (65) students who were divided into 13 sub-groups (5 students in each). These sub-groups first and before starting the clinical training were provided with an overview of Leopold's Maneuvers for about one hour. After that, they trained at the obstetric clinical skills lab by the researchers through traditional clinical demonstration of Leopold's Maneuvers through structured hands-on teaching method, explaining each method cleanly while students observe and then practice the technique. After that, the students took part in the traditional re-demonstration of procedure using the available equipment and doll of Leopold's Maneuvers. The demonstration and re-demonstration lasted for one hour and half.

**For study group**: The researcher conducted a one-day theoretical lecture using PowerPoint presentations for all obstetric nursing students in the study group and was conducted in obstetric clinical skill lab. The theoretical lecture time was divided into two sessions with 10 minutes break in-between:

*Orientation session:* "lasting for one hour" The researchers explained in detail the AI-Based Holographic Learning as a novel training strategy.

*Another session:* "lasting for one hour" was about Leopold's Maneuvers. At end of session, the researchers distributed an illustrated handout about theoretical lecture content.

Before training session, the researcher provided brief guidelines on how to use the AI based hologram technology. Then, the study group was assigned to the obstetric nursing skills laboratory in 13 sub-groups of (5 students in each). The nursing students were trained on Leopold's Maneuvers by using 3D hologram video which illustrating the steps of Leopold's Maneuvers that developed by the researchers through specialized engineers under their supervision. The practical training sessions were conducted in the obstetric nursing skill lab which took about 30 minutes for each student to practice on Leopold's Maneuvers using AI based 3D hologram.

For each sub-group, implementation of Leopold's Maneuvers which include pre procedure tasks, inspection of the pregnant woman's abdomen, palpation and auscultation. Researcher positioned a pyramid-shaped holographic structure on the top of the smartphone to create a floating 3D hologram visible video from different angles.

Then, the researcher observes each student while sitting on chair. At first, the student was a passive viewer while the video was repeated, and each step was explained by the researcher. Then, the student acted as an active Leopold's Maneuvers provider, each student carried out every step independently and the video was repeated until all students performed the procedure.

After that, the researcher facilitated group discussions to conduct a comprehensive analysis of the procedure and monitored the progress of each group, providing guidance as needed. Finally, while discussing the procedure, students were asked to point out any uncertainties or ambiguities and provide reasons for their viewpoints.

Note: The pyramid-shaped holographic structure had been disinfected with alcohol among students to protect them from cross any infection.

**Evaluation phase:**

The students from both groups appreciated the evaluation time. All students in both groups were evaluated one week after its implementation for their knowledge using **(tool: II)**, competency in Leopold's Maneuvers using (**tool: III),** students' self-confidence and their satisfaction after implementation of AI based holographic learning using **(tool III &tool: IV)**.

## Results

**As shown in table (1),** mean age of the AI based holographic learning group 22.3 ±1.2, as compared to 22.0 ±1.1of the control group. In addition, the rural area was the residence of over half of the AI based holographic learning group (53.8%) and the control group (61.5%). Majority of both groups hadn't attended any training course about AI. There were no statistically significant differences between the AI based holographic learning group and control groups regarding all Personnel data.

**As can be seen in table (2) and Figure (1):** the total mean score of

knowledge is higher in the AI-Based Holographic Learning group compared to the control group after one week of AI-Based Holographic Learning implementation; 19.8 ±6.6 versus 17.1 ±5.5 respectively with highly statistically significant difference between two groups (p≤.0.013). Additionally, the figure represents that, after one week of AI-Based Holographic Learning implementation more than half and about one third (55.4% and 23.1%) of both AI-Based Holographic Learning and control groups had respectively good level of knowledge**.**

In relation to the mean score of practices regarding Leopold's Maneuvers, **table (3) & Figure (2)** display that a higher total practices score in AI based holographic learning group compared to the control group after one week of AI-Based Holographic Learning implementation 41.7 ± 13.1 versus 34.1 ± 14.2 respectively with highly statistically significant difference between two groups (p≤.0.002).Also, more than three quarter of the study group had satisfactory practice compared to more than half of the control group.

**Table (4**) & **Figure (3):** highlighted that, there was a highly statistically significant difference of mean score self-confidence regarding Leopold's Maneuvers after AI-Based Holographic Learning implementation in the study group (11.9 ±3.4) compared to (8.0 ±2.4) in the control group (P=**<0.001**). Moreover, the figure indicates that 70.8% of the AI-Based Holographic Learning group reported a "high self-confidence" after one week of AI-Based Holographic Learning implementation, while an equal percentage of 73.8% in the control group expressed a "moderate self-confidence level ".

**Table (5) & Figure (4):** Revealed that the mean nursing student's satisfaction of the study group was15.1 ±5.1 compared to 12.1 ±5.9 of the control group after one week of AI-Based Holographic Learning implementation, Additionally, the results reveal a statistically significant difference in both groups p=0.002. Furthermore, the figure represents that more than half and less than one-third (55.4% and 29.2%) of both AI-Based Holographic Learning and control groups had high satisfaction regarding the implemented teaching strategy respectively.

**Table 1. Distribution of nursing students according to their Personnel data (N = 130)**

| | AI based holographic learning Group (n = 65) | | Control Group (n = 65) | | Test of Significance | |
|---|---|---|---|---|---|---|
| | Frq. | % | Frq. | % | $X^2$ | p-value |
| **Age (Years)** | | | | | | |
| **20-** | 20 | 30.7 | 28 | 43 | | |
| **21-** | 40 | 61.5 | 30 | 46.2 | 0.735 | 0.347 |
| **>22** | 5 | 7.7 | 7 | 10.8 | | |
| **(Mean ±SD)** | 22.3 ±1.2 | | 22.0 ±1.1 | | 1.485 | 0.139 |
| **Place of Residence** | | | | | | |
| Urban | 30 | 46.2 | 25 | 38.5 | | 0.374 |
| Rural | 35 | 53.8 | 40 | 61.5 | 0.787 | |
| **Attending any training courses about AI** | | | | | | |
| Yes | 4 | 6.2 | 1 | 1.5 | | 0.171 |
| No | 61 | 93.8 | 64 | 98.5 | 1.872 | |

**Table 2. Comparison of the Mean score of knowledge between both groups after one week implementation of AI-Based Holographic Learning regards Leopold's Maneuvers (N = 130)**

| | AI based holographic learning Group | Control Group | Significance test | |
|---|---|---|---|---|
| | Mean ±SD | Mean ±SD | T | P |
| **Knowledge domains** | | | | |
| Knowledge about AI-Based Holographic Learning | 9.3 ±2.8 | 7.8 ±2.5 | 3.186 | 0.002* |
| Knowledge about Leopold Maneuver | 10.9 ±3.2 | 9.3 ±2.9 | 2.933 | 0.004* |
| **Total knowledge score** | 20.2 ±5.7 | 17.1 ±5.2 | 3.195 | 0.002* |

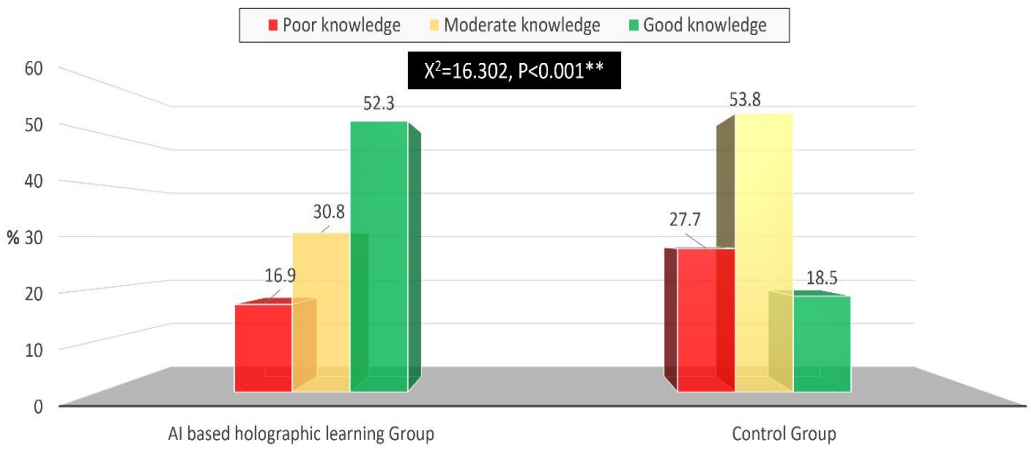


**Figure (1). Comparison of the Mean score of knowledge between both groups after one week implementation of AI-Based Holographic Learning regards Leopold's Maneuvers (N = 130)**

**Table 3. Comparison of the Mean score of practice between both groups after one week implementation of AI-Based Holographic Learning regards Leopold's Maneuvers (N = 130)**

| | AI based holographic learning Group | Control Group | Significance test | |
|---|---|---|---|---|
| | Mean ±SD | Mean ±SD | T | P |
| **Practice domains** | | | | |
| Pre procedure tasks | 12.9 ± 4.5 | 10.5 ± 4.8 | 2.944 | 0.004* |
| Fundal level measurements | 2.8 ± 1.0 | 2.3 ± 1.1 | 2.717 | 0.008* |
| Fundal grip | 2.8 ± 1.4 | 2.4 ± 1.1 | 1.827 | 0.070 |
| Bilateral grip | 2.5 ± 0.7 | 2.3 ± 1.1 | 1.246 | 0.215 |
| First pelvic grip | 4.3 ± 1.8 | 3.5 ± 1.6 | 2.712 | 0.008* |
| Second pelvic grip | 5.7 ± 2.3 | 4.7 ± 1.9 | 2.681 | 0.009* |
| Auscultation and determine position | 2.9 ± 1.2 | 2.3 ± 1.1 | 2.955 | 0.004* |
| Post procedure tasks | 7.1 ± 2.0 | 5.8 ± 2.1 | 3.611 | <0.001** |
| **Total Practice score** | 41.7 ± 13.1 | 34.1 ± 14.2 | 3.198 | 0.002* |

**Figure (2). Comparison of the Mean score of practice between both groups after one week implementation of AI-Based Holographic Learning regards Leopold's Maneuvers (N = 130)**

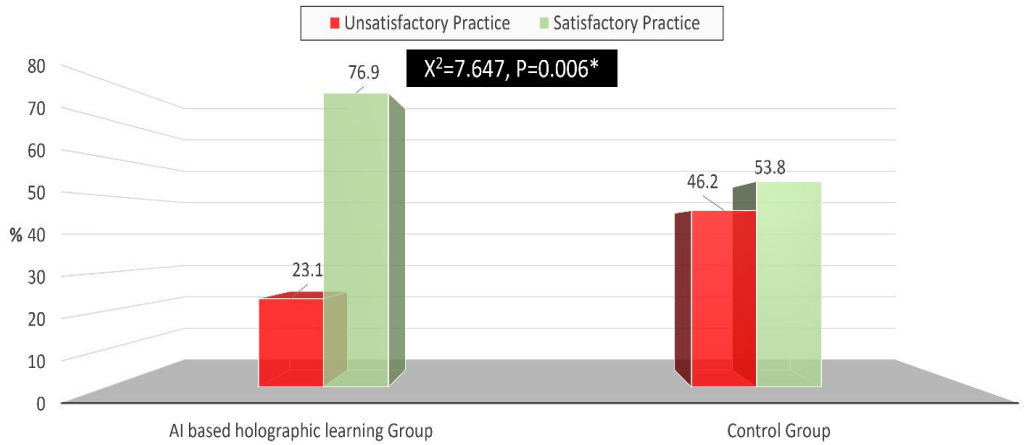

**Table 4. Comparison of the Mean score of self confidence between both groups after one week implementation of AI-Based Holographic Learning regards Leopold's Maneuvers (N = 130)**

| | AI based holographic learning Group (n = 65) | | | | | | Control Group (n = 65) | | | | | | Chi – square / | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agree | | Undecided | | Disagree | | Agree | | Undecided | | Disagree | | | |
| | Frq. | % | Frq. | % | Frq. | % | Frq. | % | Frq. | % | Frq. | % | $X^2$ | P |
| **Self-confidence items** | | | | | | | | | | | | | | |
| I feel more confident about my skills | 42 | 64.6 | 8 | 12.3 | 15 | 23.1 | 35 | 53.8 | 10 | 15.4 | 20 | 30.8 | 1.572 | 0.455 |
| I am better able to assess pregnant woman | 50 | 76.9 | 10 | 15.4 | 5 | 7.7 | 40 | 61.5 | 3 | 4.6 | 22 | 33.8 | 15.584 | <0.001** |
| The training helped me to think critically | 55 | 84.6 | 7 | 10.8 | 3 | 4.6 | 25 | 38.5 | 25 | 38.5 | 25 | 38.5 | 38.141 | <0.001** |
| Feel better prepared to care situations for real | 60 | 92.3 | 3 | 4.6 | 2 | 3.1 | 28 | 43.1 | 22 | 33.8 | 15 | 23.1 | 36.017 | <0.001** |
| I feel more confident in my decision-making skills | 62 | 95.4 | 2 | 3.1 | 1 | 1.5 | 44 | 67.7 | 6 | 9.2 | 15 | 23.1 | 17.306 | <0.001** |
| I am more confident in determining what to tell the healthcare provider | 57 | 87.7 | 3 | 4.6 | 5 | 7.7 | 23 | 35.4 | 10 | 15.4 | 22 | 33.8 | 28.286 | <0.001** |
| I feel more confident to recognize changes in my real case condition | 53 | 81.5 | 3 | 4.6 | 9 | 13.8 | 25 | 38.5 | 22 | 33.8 | 18 | 27.7 | 27.491 | <0.001** |
| **Mean ±SD** | 11.9 ±3.4 | | | | | | 8.0 ±2.4 | | | | | | 7.679 | <0.001** |

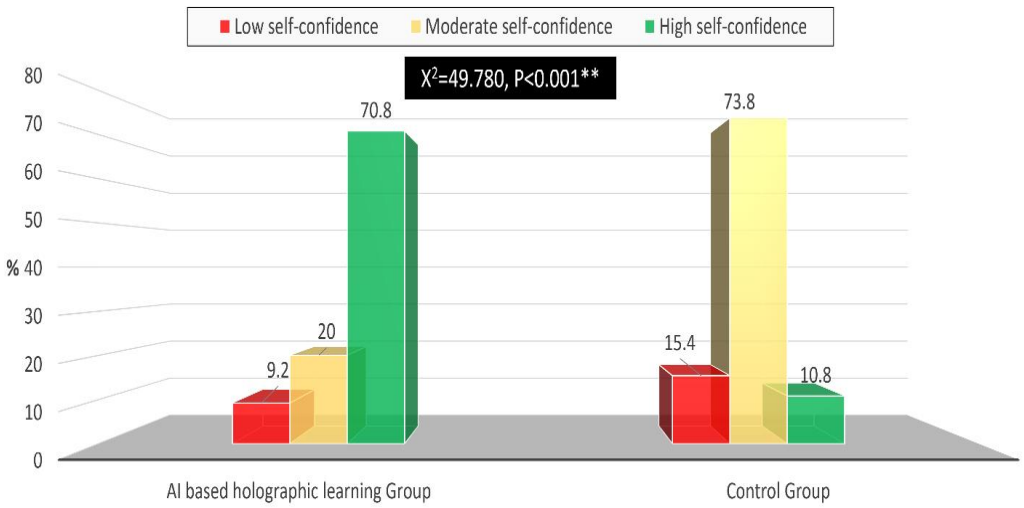


**Figure (3). Comparison of the Mean score of self confidence between both groups after one week implementation of AI-Based Holographic Learning regards Leopold's Maneuvers**
**(N = 130)**

**Table 5. Comparison of the Mean score of satisfaction between both groups after one week implementation of AI-Based Holographic Learning regards Leopold's Maneuvers (N = 130)**

| | AI based holographic learning Group (n = 65) | | | | | | Control Group (n = 65) | | | | | | Chi – square / | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agree | | Undecided | | Disagree | | Agree | | Undecided | | Disagree | | | |
| | Frq. | % | Frq. | % | Frq. | % | Frq. | % | Frq. | % | Frq. | % | $X^2$ | P |
| **Nursing student satisfaction questionnaire** | | | | | | | | | | | | | | |
| Teaching method is enjoyable | 55 | 84.6 | 5 | 7.7 | 5 | 7.7 | 28 | 43.1 | 12 | 18.5 | 25 | 38.5 | 24.998 | <0.001** |
| This method adequately addressed my information needs. | 44 | 67.7 | 4 | 6.2 | 17 | 26.2 | 25 | 38.5 | 28 | 43.1 | 12 | 18.5 | 24.093 | <0.001** |
| The knowledge and skills acquired through this method are applicable to my profession. | 45 | 69.2 | 10 | 15.4 | 10 | 15.4 | 33 | 50.8 | 7 | 10.8 | 25 | 38.5 | 8.804 | 0.012* |
| My performance improved with this method. | 52 | 80.0 | 7 | 10.8 | 5 | 7.7 | 39 | 60.0 | 11 | 16.9 | 15 | 23.1 | 7.738 | 0.020* |
| Learning occurred more efficiently with this method. | 50 | 76.9 | 7 | 10.8 | 8 | 12.3 | 40 | 61.5 | 2 | 3.1 | 23 | 35.4 | 11.146 | 0.004* |
| I perceive learning to be more effective with this approach | 46 | 70.8 | 4 | 6.2 | 15 | 23.1 | 36 | 55.4 | 14 | 21.5 | 15 | 23.1 | 6.775 | 0.033* |
| This method enhanced my motivation to learn. | 56 | 86.2 | 4 | 6.2 | 5 | 7.7 | 29 | 44.6 | 11 | 16.9 | 15 | 23.1 | 16.121 | <0.001** |
| The subject matters more engaging with this approach. | 50 | 76.9 | 8 | 12.3 | 7 | 10.8 | 36 | 55.4 | 4 | 6.2 | 25 | 38.5 | 13.737 | <0.001** |
| This method enhanced my clinical judgment. | 48 | 73.8 | 5 | 7.7 | 12 | 18.5 | 28 | 43.1 | 8 | 12.3 | 29 | 44.6 | 13.004 | 0.002* |
| Overall satisfaction with this teaching method. | 40 | 61.5 | 12 | 18.5 | 13 | 20.0 | 35 | 53.8 | 15 | 23.1 | 15 | 23.1 | 0.809 | 0.667 |
| Recommend implementing this method in other educational settings. | 52 | 80.0 | 8 | 12.3 | 5 | 7.7 | 30 | 46.2 | 20 | 30.8 | 15 | 23.1 | 16.045 | <0.001** |
| **Mean ±SD** | **15.1 ±5.1** | | | | | | **12.1 ±5.9** | | | | | | **3.109** | **0.002*** |

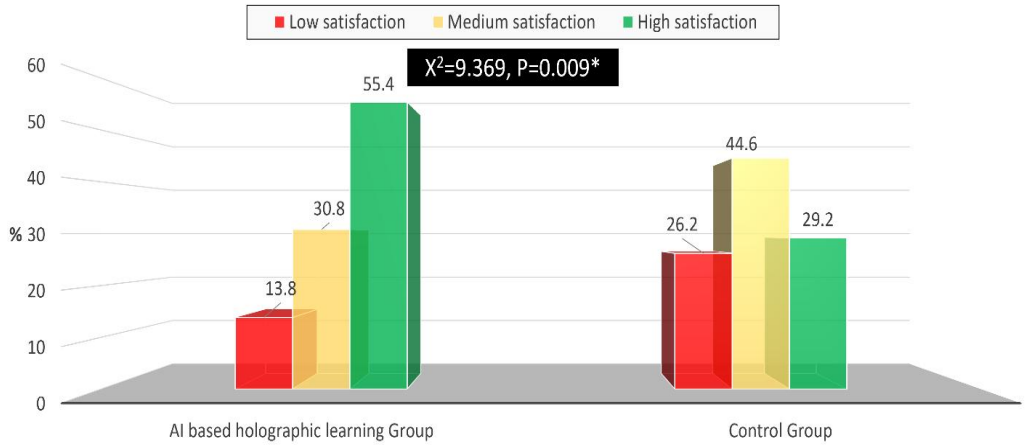


**Figure (4). Comparison of the Mean score of satisfaction between both groups after one week implementation of AI-Based Holographic Learning regards Leopold's Maneuvers (N = 130)**

## Discussion

The role of technology in education has revolutionized the learning process and provided teachers with new and innovative ways to teach students the integration of technology into education had a positive impact on learners and instructors. Technology improves control, transmission, and acquisition of information by learners **(Alghamdi, 2020).** This study demonstrated that AI-based holographic learning is an effective educational innovation that significantly improves nursing students' knowledge, psychomotor competence, self-confidence, and satisfaction in performing Leopold's maneuvers. The central objective of this study was to evaluate effect of implementing Artificial Intelligence-Based Holographic learning on nursing students' competence in leopold's maneuvers.

The findings supported the study's hypotheses that: **H1:** No statistically significant difference in mean score of Leopold's Maneuvers knowledge at posttest between students who receive AI-Based Holographic Learning and those who receive traditional methods.

**H2:** No statistically significant difference in mean score of nursing student's skills at posttest between students who receive AI-Based Holographic Learning and those who receive traditional methods.

**H3:** No statistically significant difference in mean score of nursing student's confidence at posttest between students who receive AI-Based Holographic Learning and those who receive traditional methods.

**H4:** No statistically significant difference in mean score of nursing student's satisfaction at posttest between students who receive AI-Based Holographic Learning and those who receive traditional methods.

The analysis of personal data discovered that most participants in both groups were in their early twenties, with a mean age of 22.3 years in the AI-based holographic group and 22.0 years in the control group. This finding is consistent with the expected age range of undergraduate nursing students in their third academic year, who are typically enrolled in obstetric nursing courses **(Gaur, Mudgal, Kaur, & Sharma, 2020).** The similarity in age distribution between groups ensures comparability and minimizes age-related bias in learning outcomes.

Regarding prior training in artificial intelligence, almost all students in both groups had no previous exposure. This finding is in line with **Gabr, Sleem, and El-wkeel (2025),** who reported that nursing students in Egypt had minimal prior experience with virtual reality or AI-based educational tools. The lack of prior training underscores the novelty of AI-based holography in nursing education and confirms that the improvements observed in this study were attributable to the intervention itself rather than pre-existing familiarity with the technology. Overall,

the homogeneity of the groups in terms of age, residence, and prior training strengthens the validity of the study outcomes by ensuring that differences in knowledge, skills, confidence, and satisfaction.

When it came to the hypothesis H1, the total mean score of knowledge is higher in the AI-Based Holographic Learning group compared to the control group after one week of implementation. This suggests that the hologram provides the authentic and realistic projection for better understanding. Learning has become much simpler and more effective. Holographic images help to develop mental patterns that incorporate with visual images and helps in understanding and retaining of that topic than the rational methods of teaching and supervising **(Mukhallafi, 2023).**

Similar results were reported by **Chan, Roberts, and Lee (2024),** who found that AI-enhanced adaptive platforms improved clinical reasoning by tailoring feedback to learners' performance. Likewise, **Li, Xu, and Chen (2023)** emphasized that holographic and AI-driven environments promote deeper conceptual understanding through spatial visualization. In contrast, **Visan et al. (2025)** observed that while virtual reality training improved theoretical knowledge in obstetric procedures, its superiority over traditional methods was less conclusive. This suggests that AI integration, rather than virtual reality alone, may explain the stronger knowledge outcomes observed in the present study.

The study also revealed that students trained with holographic technology demonstrated significantly higher practice scores across multiple components of Leopold's maneuvers. A possible explanation for the significant improvement of students' practice is students have better visualization of objects with animation of paper folding that floats in the 3D space of the hologram pyramid. This visual image representation resembled real objects. Thus, it is easier for students to create abstract images in their mind which helped them when answering related questions **Elmarash G. A., Adrah M. M, and Eljadi E. E., (2021**).

These results align with **Asadipour et al. (2020)**, who demonstrated that technology-assisted palpation training enhanced procedural accuracy by providing multimodal feedback. Similarly, **Jongbloed, Chaker, and Lavoué (2024)** concluded that holographic learning allow repeated, error-tolerant practice that bridges the gap between theoretical instruction and hands-on competence. Additionally, **(Akram, Khalil, & Ahmad, 2023).** They also found that AI systems enable real-time assessment and feedback, creating individualized learning pathways that enhance both procedural accuracy and confidence. Moreover, holographic visualization offers spatial realism that surpasses traditional simulation, allowing learners to practice maneuvers repeatedly without risk to patients However, **Stritzke,**

**Murthy, and Fiedrich (2023)** noted that simulation-based training, while effective, may still be vulnerable to skill decay over time unless supplemented with clinical exposure.

A notable outcome of this study in which there was a highly statistically significant difference of mean score self-confidence regarding Leopold's Maneuvers after AI-Based Holographic Learning implementation in the study group compared to the control group (P=**<0.001**). Also, more than two-thirds of the study group reported high confidence levels compared with the control group. This finding is in line with **Sinurat et al. (2025),** who reported that virtual reality significantly improved nursing students' self-confidence across interprofessional training contexts.

**Park et al. (2023)** also observed that virtual reality-based simulation programs strengthened students' confidence in decision-making and patient care. Confidence is a critical determinant of clinical readiness, as it influences both skill application and patient interaction. However, some scholars caution that confidence gained in simulated environments may not always translate into sustained performance in real clinical settings **(Stritzke et al., 2023).**

These findings are explained by the fact that integration of AI technology in the learning process succeeds in creating a more interactive and interesting learning environment for students. Also, providing personalized feedback allows each student to be actively involved in the learning process according to their individual abilities and pace. In addition, the positive impact of (AI)-based learning on student metacognition, which is the awareness and self-control of the thinking process. Thus, AI-based learning not only increases students' engagement but also encourages them to become independent and responsible learners with increasing their self-confidence **(Riski D& Nuryanto A, 2024**).

In addition to competence and confidence, the study demonstrated significantly higher satisfaction among students trained with holographic learning. Most participants in the experimental group reported that the method was enjoyable, motivating, and efficient in facilitating learning. These findings resonate with **Jallad et al. (2024),** who found high satisfaction levels among students using immersive virtual reality for anatomy courses, and **Li, Chen, and Wang (2023),** who confirmed that AI technologies significantly enhance learning satisfaction compared to conventional instruction. **Yet, Hennekeuser, Müller, and Schröder (2024)** argued that technology alone may not guarantee satisfaction; the role of expert facilitation and structured pedagogy remains essential to optimize learner engagement.

These outcomes demonstrated the critical function of AI based holographic learning in Leopold's maneuvers which can attract students' attention and interest through the ability to master and apply modern

vocational education, not only focuses on the immediate performance implications but also delves deeply into the far-reaching impacts **( Dwivedi et als.,2021)** .

Overall, the findings of this study support the growing body of evidence that AI- based holographic learning driven technologies can address critical gaps in clinical training by providing equitable, standardized, and safe opportunities for skill acquisition. As noted by **Zhao, Hu, and Wang (2023),** Nevertheless, in resource-constrained environments, low-cost simulators may still serve as valuable alternatives **(Hanson et al., 2024),** highlighting the importance of context-specific solutions.

## Conclusion

In conclusion, the present study found that AI-based holographic learning proved more effective than traditional methods in enhancing knowledge, clinical competence, confidence, and satisfaction regarding Leopold's maneuvers.

## Recommendations

Based on the findings of this study, several recommendations can be proposed for nursing and midwifery education as well as for future research:

1. AI-based holographic learning should be incorporated into midwifery programs as an adjunct to conventional instruction.
2. Embedding holography in clinical courses, particularly obstetric modules, can ensure equitable access to standardized practice opportunities and reduce variability in clinical exposure.
3. Further comparative studies between AI-holography, virtual reality, and traditional simulation would provide clearer evidence of relative effectiveness.

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## References

**Ahmed, H., Ali, R., & Elshaer, I. (2022).** Student satisfaction and performance using mixed reality in medical education: A pilot study. *BMC Medical Education, 22*(1), 395. https://doi. org/ 10. 1186/ s12909-022-03439-0

**Akram, A., Khalil, J., & Ahmad, N. (2023).** Holography in medicine: Three-dimensional visualization for surgeons. *Journal of Medical Imaging and Health Informatics*, 13(4), 811–819. https://doi. org/ 10.1166/jmihi.2023.4002

**Alghamdi, A. (2020):** Analyzing the barriers and possibilities with p-values towards starting a new postgraduate computer and engineering program at Najran university: A cross-sectional study. International Journal of Advanced Computer Science and Applications (IJACSA), 11(12).

https:// doi. org/ 10.14569/IJACSA.2020.0111215.

**Asadipour, A., Debattista, K., Patel, V., & Chalmers, A. (2020).** A technology-aided multi-modal training approach to assist abdominal palpation training and its assessment in medical education. *arXiv*. https://doi.org/10.48550/arXiv.2001.05745

**Borim Nejad LB, Sajadi Hezaveh M, Khosravi S. (2015).**The Effect of Learning Contract on Self-directed learning and satisfaction of nursing students in Clinical Education. Iran J Med Educ, 14(12):1084–92.

**Brown, A. L., Smith, J., & Patel, V. (2022).** HoloLens for procedural training: A systematic review. *Simulation in Healthcare, 17*(5), 345–356.

**Bukhari, S., Khan, T., & Malik, R. (2020).** Enhancing Leopold Maneuver practice using digital simulation. *BMC Medical Education, 20*(1), 457. https://doi. org/ 10.1186/s12909-020-02352-y

**Chan, K. S., Roberts, L., & Lee, C. (2024).** Adaptive learning in clinical reasoning using AI platforms. *BMJ Innovations, 10*(1), 12–19. https:// doi. org/ 10. 1136/ bmjinnov-2023-000947.

**Ditzel, L., & Collins, E. (2021).** Holograms in nursing education: Results of an exploratory study. *Journal of nursing education and practice*, *11*(8), 43.

**Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., Duan, Y., Dwivedi, R., Edwards, J., Eirug, A., Galanos, V., Ilavarasan, P. V., Janssen, M., Jones, P., Kar, A. K., Kizgin, H., Kronemann, B., Lal, B., Lucini, B., ... Williams, M. D. (2021).** Artificial Intelligence (AI): Multidisciplinary Perspectives on Challenges, Opportunities, and Emerging Agendas for Research, Practice, and Policy. International Journal Of Information Management, 57, 101994. Https://Doi. Org/10.1016/J.Ijinfomgt.2019.08.002

**Elmarash, G., Adrah, M., & Eljadi, E. (2021).** 3D hologram technology in Libyan educational institutions in future: Review. *Sebha University Journal of Pure & Applied Sciences, 20*(3), 7–9. vol. 20, no. 3, pp. 6–10, doi: 10. 51984/ jopas. v20i3.1000.

**Gabr, M. A. M., Sleem, W. F., & El-wkeel, N. S. (2025).** Effect of virtual reality educational program on critical thinking disposition among nursing students in Egypt: A quasi-experimental pretest–posttest design. *BMC Nursing, 24*(1), 188. https://doi.org/10.1186/s12912-025-03488-w

**Gaur, R., Mudgal, S. K., Kaur, S., & Sharma, R. (2020).** Undergraduate nursing students' attitude towards online classes during lockdown period in India: Imposed or interested? *International Journal of Community Medicine and Public*

*Health, 7*(9), 3371–3377. https://doi.org/10.18203/2394-6040.ijcmph20203892

**Hanson, C., Murthy, P., Fiedrich, E., et al. (2024).** Nursing and midwifery simulation training with a newly developed low-cost high-fidelity placenta simulator: A collaboration between Italy and Ethiopia. *BMC Medical Education, 24*, 1191. https://doi.org/10.1186/s12909-024-06152-0

**Hennekeuser, D., Vaziri, D. D., Golchinfar, D., Schreiber, D., & Stevens, G. (2024).** Enlarged education—Exploring the use of generative AI to support lecturing in higher education. *International Journal of Artificial Intelligence in Education*, 34(2), 1–33. https://doi.org/10.1007/s40593-024-00392-9

**Hennekeuser, M., Müller, L., & Schröder, K. (2024).** Enlarged education—Exploring the use of generative AI to support lecturing in higher education. *Frontiers in Education, 9*, 1379658. https://doi.org/10.3389/feduc.2024.1379658

**Jallad, S., Natsheh, I., Helo, L., Ibdah, D., Salah, A., Muhsen, R., & Froukh, N. (2024).** Nursing students' perceptions, satisfaction, and knowledge toward utilizing immersive virtual reality application in human anatomy course: A quasi-experimental study. *BMC Nursing, 23*, 601. https://doi.org/10.1186/s12912-024-01794-8

**Jongbloed, J., Chaker, R., & Lavoué, E. (2024).** Immersive procedural training in virtual reality: A systematic literature review. *Computers & Education, 221*, 105124. https://doi.org/ 10. 1016/ j. compedu. 2024.105124

**Koh, C. W., Lee, P. S., & Teo, M. H. Y. (2021).** Obstetric simulation training: Enhancing student confidence and clinical competence. *Medical Education Online, 26*(1), 1914562. https://doi. org/ 10. 1080/ 10872981.2021.1914562

**Li, J., Xu, M., & Chen, W. (2023).** Holographic and AI-driven education in medical training: A scoping review. *Journal of Medical Systems, 47*(1), 15. https://doi.org/10.1007/s10916-023-01918-3

**Li, X., Chen, Y., & Wang, Z. (2023).** The effectiveness of virtual reality teaching, especially immersive virtual reality, in improving nursing students' learning satisfaction: Systematic review and meta-analysis. *Nurse Education Today, 124*, 105722. https:// doi.org /10.1016 /j.nedt.2023.105722

**Mohammed SA and Ahmed HM. (2016):** The Effect of Simulation Training on Nurses and Intern Nursing Students' Skill, Confident and Satisfaction Regarding Neonatal Resuscitation. IOSR Journal of Nursing and Health Science (IOSR-JNHS), 5(5): 17-27

**Mousa, M. A., Khalaf, D. R., & Younes, M. A. (2023).** Learner satisfaction with immersive virtual and holographic simulations in clinical training. *Education and Information Technologies, 28*(7), 8815–8830. https://doi.org/ 10. 1007/ s10639- 023-11899-2

**Mukhallafi, T. R. Al 2023.** "The Effect of Utilizing Hologram Technology on Developing EFL Communication Skills and Attitudes towards English among Middle School Students," *Stud. English Lang. Teach.*, vol. 11, no. 2, p. p1, doi: 10.22158/selt.v11n2p1.

**Park, J.-Y., Kim, S., Lee, H., & Choi, Y. (2023).** Development and effects of a virtual reality simulation nursing education program. *CIN: Computers, Informatics, Nursing, 41*(7), 437–445. https://doi.org/10.1097/CIN.0000000000000924

**Riski D, Nuryanto A, 2024.** The Effect of Artificial Intelligence (AI) Based Learning Implementation on the Quality of Learning Outcomes of Vocational High School Students in the Field of Machining. IJSSHR, Volume 07 Issue 09. DOI: 10.47191/ijsshr/v7-i09-18

**Shimizu, T., Tanaka, K., & Yamada, H. (2021).** Skill degradation in obstetrics without clinical exposure: Implications for training. *Medical Teacher, 43*(11), 1285–1292. https://doi.org/ 10. 1080/0142159X.2021.1898592

**Sinurat, S., Karo, M. B., Simbolon, R., Saragih, I. D., Tarihoran, D. E. T. A. U., Sharma, S., & Chou, F. H. (2025).** The efficacy of virtual-reality teaching and learning method in enhancing interprofessional knowledge, clinical skill performance, and self-confidence in nursing education: A systematic review and meta-analysis. *Nurse Education Today, 132*, 106661. https://doi. org/ 10. 1016/ j.nedt.2025.106661

**Stritzke, A., Murthy, P., & Fiedrich, E. (2023).** Advanced neonatal procedural skills: A simulation-based workshop—Impact and skill decay. *BMC Medical Education, 23*, 26. https:// doi. org/ 10. 1186/s12909-023-04000-1

**Visan, I. G., Toma, C. V., Petca, R., Petrescu, G. E. D., Noditi, A.-R., & Petca, A. (2025).** Exploring the efficacy of virtual reality training in obstetric procedures and patient care: A systematic review. *Healthcare, 13*(7), 784. https://doi.org/10.3390/healthcare13070784

**Yu Q, Li B & Wang Q (2022).** The effectiveness of 3D holographic technology on students' learning performance: a meta-analysis, Interactive Learning Environments, DOI: 10.1080/ 10494820. 2022.2124424

**Zhao, Y., Hu, Y., & Wang, X. (2023).** AI-based assessment tools in clinical skill training: A review of emerging applications. *Advances in Medical Education and Practice, 14*, 1011–1020. https://doi. org/10.2147/AMEP.S421347