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(Research Article)

# The benefits of simulation-based learning in improving knowledge and safety practices related to the preparation of cytotoxic drugs among pharmacy students

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## Abstract

Context: Preparing cytotoxic drugs poses serious safety risks for pharmacy technicians. Lack of knowledge regarding proper preparation techniques can lead to occupational exposure risks and therapeutic errors.

Objective: This study aims to evaluate the impact of a first-time simulation session integrated into pharmaceutical studies in Morocco on third-year pharmacy students' knowledge of good practices for preparing cytotoxic drugs.

Method: A simulation session was conducted with 39 students. The session comprised three stages: briefing, scenario, and debriefing. The scenario consisted of four stations, ranging from pharmaceutical validation to shipment of the preparation.

Students were given a questionnaire before and after the simulation session to assess their knowledge. The percentage of correct answers was compared.

Results: A significant improvement in knowledge was observed for all items. The average percentage of correct answers increased from 48.2% in the pretest to 87.6% in the posttest ($p < 0.001$). The most significant progress was made in pharmaceutical validation of the chemotherapy protocol (increasing from 44% to 86%), identification of preparation equipment (increasing from 47% to 88%), labeling rules (increasing from 41% to 89%), dressing rules (increasing from 38% to 84%), and disposal of cytotoxic waste (increasing from 45% to 87%).

Conclusion: Simulation is an effective teaching tool that pharmacy educators can use to rapidly and sustainably improve pharmacy students' knowledge of safe cytotoxic preparation and other hospital pharmacy-related topics.

**Keywords:** Healthcare simulation; Cytotoxic drug; Simulation session; Good preparation practices

## 1. Introduction

Cytotoxic drugs are toxic chemical molecules that destroy cancer cells through various mechanisms [1]. Most are administered parenterally and require dilution and/or reconstitution in accordance with good preparation practices before administration.

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Handling injectable cytotoxic drugs exposes healthcare professionals to chemical, cutaneous-mucosal, and environmental risks [2]. Safe preparation requires strict adherence to protocols, including the use of personal protective equipment and validated procedures for preparation, labeling, and waste disposal [3]. However, pharmacy students' initial training in these specialized procedures is often theoretical.

Healthcare simulation is a relevant method for establishing good practices through experiential learning [4]. It provides a controlled environment for learning, practicing, and correcting errors without real risks.

This study aims to evaluate the impact of a simulation session on pharmacy students' knowledge of the cytotoxic drug preparation process.

## 2. Methods

- **Type of study**: A pre-post educational study was conducted among third-year pharmacy students during the 2023-2024 academic year. The simulation session took place at the simulation center of the Faculty of Medicine and Pharmacy in Tangier, which was specially equipped to replicate the real conditions of a cytostatic reconstitution unit.
- **Population:** The study included the entire third-year pharmacy class, comprising 39 students who had received theoretical training in the preparation of cytotoxic drugs but had no prior experience in chemotherapy preparation. No exclusion criteria were applied, allowing for a comprehensive assessment of training needs.
- **Simulation session:** The simulation session was structured in three distinct stages:

**The Briefing (15 min):** The briefing is a step before the simulation, the purpose of which is to present the subject and explain the scenarios. A structured presentation was given, including:

  - A reminder about the preparation of cytotoxic drugs and the risks associated with errors in their handling.
  - A presentation of the educational objective of the simulation session, which is to master the cytotoxic drug preparation process.
  - Assignment of roles to volunteers: pharmacist, preparer, assistant preparer, and observers.
  - An explanation of the scenario and instructions for participants.

**The simulation or scenario (30 min):** The simulation took place in a room separate from the briefing/debriefing room at the simulation center of the Faculty of Medicine and Pharmacy in Tangier. The room is equipped with educational video surveillance devices that transmit the scenario in real time to the briefing/debriefing room. The room has four stations representing the cytotoxic preparation process: pharmaceutical validation, order preparation, airlock (dressing and hand disinfection), and laminar flow hood (actual preparation). The scenario participants went through the different stations, and the observers noted the various errors made by the participants.

**The Debriefing (60 minutes):** A structured debriefing aimed at transforming the simulation experience into concrete learning. This step allows for a collective analysis of the difficulties encountered, correction of the errors observed and their causes, reformulation of the key points, and a recap of the steps that were carried out correctly. A structured presentation was given, including:

  - Occupational risks (acute and chronic toxicity)
  - Regulations governing controlled areas (Controlled atmosphere area)
  - Principles of operation of vertical laminar flow hoods
  - Procedures for validating chemotherapy prescriptions
  - Labeling and traceability rules
  - Safe management of cytotoxic waste.

- **Evaluation**: Students were assessed using a 15-item questionnaire covering all the competency areas required for the safe preparation of cytotoxic drugs before the briefing (pre-test) and after the debriefing (post-test). Topics covered included:
  - Pharmaceutical analysis and prescription validation
  - Labeling rules
  - Choice of dilution and/or reconstitution solvents
  - Controlled atmosphere areas and preparation equipment
  - Dressing, preparation, and/or reconstitution steps
  - Occupational hazards related to exposure to cytotoxic drugs
  - Calculation of volumes withdrawn during reconstitution or preparation

  - Waste Disposal Procedure.
- **Statistical Analysis**: Results are presented as percentages of correct answers. Scores were compared using the McNemar [5] test, which allows for the comparison of up to two measured values.

## 3. Results

Analysis of data collected from 39 pharmacy students revealed significant knowledge improvement after the simulation session. The participation rate remained high throughout the study, with 100% responding to the pre-test and 97.4% responding to the post-test (Figure 1).

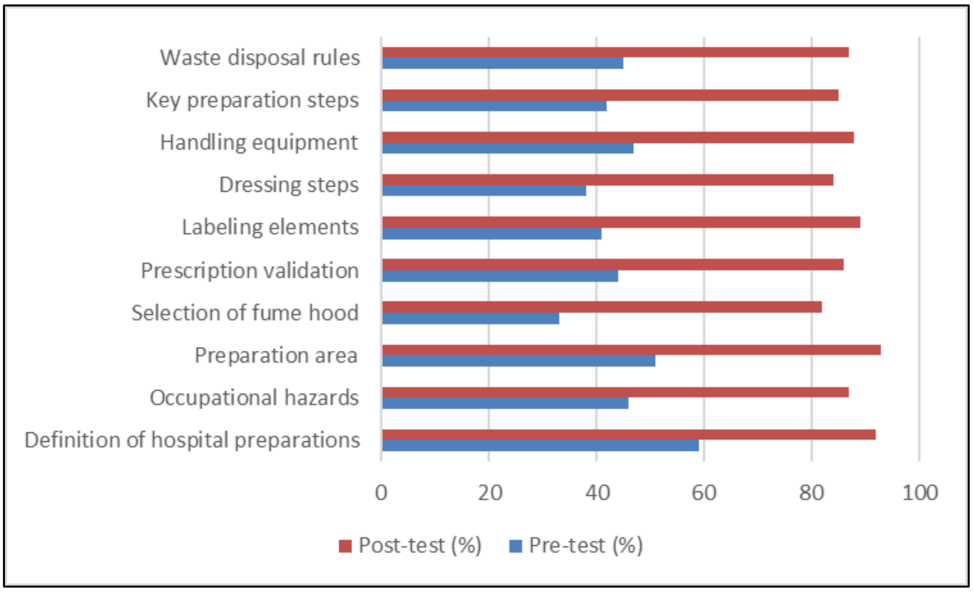


**Figure 1** Percentages of correct answers before and after the simulation session

The average percentage of correct answers increased from 48.2% (±8.3%) on the pretest to 87.6% (±5.1%) on the posttest, representing an absolute increase of 39.4 points ($p<0.001$). This improvement was observed across all assessed areas, particularly in the practical aspects of preparation.

- **Overall Assessment of Student Knowledge:** Analysis of student knowledge reveals an improvement in learning from the pre-test to the post-test. In fact, 35% of students earned a perfect score on the post-test, and 92% scored above 80%. The percentage of students who scored below 60%, indicating difficulty, decreased from 17% to 0%.
  The average response time decreased by approximately 50%, from 18.7 minutes (± 4.2) on the pre-test to 9.3 minutes (± 2.1) on the post-test.
- **Knowledge of the environment, equipment, and materials used for the safe preparation of cytotoxic drugs**: A question asked about the choice of a laminar flow hood used for cytotoxic preparation. This hood protects both the operator and the preparation. The assessment revealed that students' knowledge improved from 33% before the simulation session to 82% afterward. Students were also assessed on their ability to identify the specific equipment required for cytotoxic preparation. The percentage of correct answers increased from 47% on the pretest to 88% on the posttest. Finally, recognition of the appropriate area (controlled atmosphere or isotechnical area) for cytotoxic preparation improved from 51% to 93%.
- **Mastery of Operational Procedures:** Students' knowledge of labeling rules and mandatory information to include on preparation labels increased from 41% before the simulation session to 89% afterward. Similarly, adherence to the chronological order for putting on personal protective equipment improved significantly, with the percentage of correct answers rising from 38% in the pretest to 84% in the posttest. Additionally, knowledge of essential preparation steps, including labeling, calculating the volume to be dispensed, and quality control, progressed, rising from 42% to 85%.
- **Regulatory and Safety Knowledge:** There has been significant progress in mastering the key elements necessary for the pharmaceutical validation of chemotherapy protocols, increasing from 44% to 86%. Identification of occupational risks related to handling anticancer drugs increased from 46% to 87%. Finally, knowledge of rules relating to the disposal of cytotoxic waste progressed from 45% to 87%.

- **Knowledge of Other Principles:** The following principles were assessed and showed improvement before and after the simulation session, the difference between hospital and pharmacy preparations (improved from 59% to 92%), knowledge of preparation devices (improved from 52% to 89%) and choice of diluents for reconstitution and/or preparation of medicines (improved from 50% to 89%)

## 4. Discussion

Integrating educational simulation into health sciences education, particularly pharmaceutical studies, is a modern, effective learning method that improves future pharmacists' knowledge and skills. Indeed, simulation enables the reproduction of realistic situations in a controlled environment, promoting learning by doing in a safe and effective manner.[6] Furthermore, simulation allows students to repeat techniques multiple times and learn from mistakes without risking patient safety.[7]

The results of our study are consistent with the literature on the contribution of simulation to healthcare training [8,9] and, more specifically, to hospital pharmacy training.[10]

From a pedagogical standpoint, simulation helps reduce the gap in achievement among students. This is explained by the results of our study, which show that all students improved their performance, with 92% of participants achieving a score above 80% on the post-test. Indeed, active learning approaches such as simulation promote student engagement and facilitate knowledge acquisition compared to traditional teaching methods [11]

Furthermore, the significant reduction in students' response time before and after the simulation session suggests an improvement in cognitive efficiency. Indeed, repeated practice in a simulation session makes skills automatic, and consequently, decision-making in a given situation becomes easier and faster [12]. In the context of cytotoxic drug preparation, this cognitive automatization improves practice efficiency and reduces the risk of occupational exposure.

From a practical standpoint, the results of our study demonstrate a significant improvement in students' knowledge of all assessed items. This improvement highlights the positive impact and importance of this educational tool for mastering high-risk practices, such as preparing cytotoxic drugs.

The most significant improvements were observed in the areas of environment and equipment. The choice of a vertical laminar flow hood was particularly impactful. This hood protects the technician from exposure to cytotoxic drugs and protects the preparation from contaminants. The increase from 33% to 82% demonstrates the effectiveness of the practical demonstration in conveying the benefits of this equipment for protecting both technicians and preparations. Several studies have shown that manipulating or observing the operation of preparation equipment in a simulated context improves memorization and understanding of equipment operation and protection principles. [13, 14]

This study demonstrated the value of simulation in learning and mastering technical skills, such as hand disinfection, proper timing of personal protective equipment use, and labeling rules for cytotoxic preparations, in accordance with good hospital and preparation practices [15, 16]

Knowledge of occupational risks associated with handling cytotoxic drugs and managing waste was assessed and improved after the simulation session. Raising students' awareness of these principles helps minimize exposure to cytotoxic anticancer drugs and prevent occupational accidents.

## 5. Conclusion

This study clearly shows the major benefits of simulation in training pharmacy students, especially for high-risk activities like preparing anticancer drugs. Analysis of the results reveals a remarkable increase in correct answers, confirming the immediate impact of this experiential learning method.

Integrating educational simulation into pharmacy curricula could improve training quality, strengthen professional practice safety by creating a secure learning environment, and better prepare future pharmacists for professional demands.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

### *Statement of informed consent*

"Informed consent was obtained from all individual participants included in the study."

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