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MANAGEMENT OF THE PROFESSIONAL TRAINING PROCESS THROUGH THE APPLICATION OF SIMULATION METHODS IN UNIVERSITY MEDICAL EDUCATION

331.03 - SOCIAL MEDICINE AND MANAGEMENT

Abstract of the PhD Thesis in Medical Sciences

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The thesis was developed within the Department of Social Medicine and Management "Nicolae Testemitanu" and the University Center for Simulation in Medical Training, Nicolae Testemitanu State University of Medicine and Pharmacy.

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CONTENTS

CONCEPTUAL FRAMEWORK OF THE RESEARCH

Relevance and significance of the topic. In the context of increasing demands for training, limited patient interaction, and the prioritization of patient safety, a new concept has emerged in medical education, integrating advanced technologies and innovative teaching methods. Simulation-based medical training is an educational process that utilizes simulators, clinical scenarios, and specialized technologies to replicate real medical situations. Its purpose is to develop and evaluate theoretical, practical, and communication skills in a controlled, safe, and ethical environment, without risks to patients. Simulation in medical education has immense potential for widespread application throughout the education system, from undergraduate to postgraduate levels and continuing medical education. Recent developments, such as the right to clinical practice during the residency stage, have increased the focus on professional medical training at the university level. The benefits of clinical simulation are increasingly reported in specialized literature, and its integration into curricula requires careful planning [1–3].

The implementation of simulation at the Nicolae Testemițanu State University of Medicine and Pharmacy began in 2003 with the use of standardized patient methodology in university training. The establishment of the University Center for Simulation in Medical Training (CUSIM) facilitated the enhancement and diversification of simulation-based medical training methods across all levels of professional education. Recent changes in licensing regulations and new responsibilities assigned to medical trainees have made it essential to increase the complexity and utility of developing practical competencies for students, particularly in the final years of their studies [30 – 35]. The complementarity of medical simulation must be justified and strategically applied to meet the requirements of the national healthcare system in alignment with policies for training specialized human resources. [4, 12, 24, 25].

The goal of medical education is to develop the skills of physicians capable of providing a high level of care in safe conditions for patients. Identifying the optimal methods and necessary elements to achieve educational objectives remains an ongoing challenge [5, 13, 14]. Over the past two decades, simulation has significantly enhanced the concept of traditional medical training, with its use increasing exponentially. Drawing on experiences from fields such as aviation and astronautics, efforts have been made to refine effective methods for utilizing simulation in medical education [6, 15, 16].

Description of the field situation and identification of the research problem. Simulation-Based Medical Education (SBME) has become fundamental in training healthcare professionals, providing a dynamic and interactive learning environment that mirrors clinical realities without compromising patient safety. It allows learners to practice procedures, make decisions, and manage patient interactions in a controlled setting, thereby enhancing their clinical skills, critical thinking, and confidence before practicing in real-world scenarios [1, 17, 18, 26, 27]. The significance of SBME lies in bridging the gap between theory and practice, providing an essential platform for experiential learning, and thereby preparing competent and efficient healthcare providers [7, 19, 22, 23].

The complexity of modern healthcare systems and the need for high-quality care demand innovative educational approaches that adequately prepare students for the challenges of clinical practice [8, 9, 20, 21]. Simulation-based approaches are essential, providing an effective means of teaching clinical skills, improving decision-making, and enhancing professional competencies in a safe environment [10, 11, 34].

The formulated research hypothesis asserts that simulation sessions, implemented based on a rigorous methodology, can have a significant impact on clinical skills, student satisfaction, and the standardization of the educational process in higher medical education.

The research aims to identify optimal strategies for integrating simulation into national university programs by developing a procedural framework to implement simulation-based methods. The ultimate goal is to enhance the quality and effectiveness of medical education and to train graduates with transferable and generalizable professional competencies. Additionally, the research explores simulation techniques and methodologies, evaluating their merits and disadvantages while improving the understanding of simulation customization to meet specific needs based on available facilities and instructional objectives.

Research aim: The development and validation of an efficient methodology for the application of simulation in university medical education, aimed at enhancing teaching quality and strengthening the management of the professional training process.

General objectives of the thesis:

1. Development of the procedural framework by determining the need for and organizing simulation training at the university level.
2. Evaluation of students' acquisition of practical skills through the observational method, using checklists as an assessment tool.
3. Analysis of the impact of training on students' theoretical knowledge through the application of pre- and post-training testing procedures.
4. Determination of student satisfaction with the applied components of medical simulation training.
5. Development of recommendations for the comprehensive and efficient implementation of medical simulation training at the university level.

Scientific research methodology. The research focused on evaluating the effectiveness of simulation-based training in university medical education at the University Center for Medical Simulation of the Nicolae Testemițanu State University of Medicine and Pharmacy. The study, analytical and experimental in nature, involved students divided into groups based on the practical skills being trained. Due to certain limitations, a quasi-experimental design was employed to assess the impact on theoretical and practical skills. Data were collected using written tests, checklists, and questionnaires, employing historical, mathematical, and sociological methods. The analysis was performed using specialized software, which facilitated the application of statistical tests and the validation of the research hypothesis.

The scientific novelty and originality of the results obtained. The research conducted at Nicolae Testemițanu State University of Medicine and Pharmacy introduced an innovative methodology for implementing simulation-based training in university medical education. This approach incorporated diverse simulation methods, such as standardized patients and integrated clinical scenarios, which had not been previously applied in a structured educational setting. The originality of the research lies in a comprehensive pre- and post-intervention evaluation system that measured theoretical knowledge, clinical competencies, student satisfaction, and adaptability to unexpected situations. The results demonstrated a significant improvement in student performance, validating the effectiveness of simulation and proposing it as a standard for national medical education. The study highlighted the importance of integrating advanced technologies into the curriculum and opened new avenues for adapting the methodology.

The important scientific problem addressed in the thesis. The research was initiated to address the need for improving the professional training of medical students in the context of increasing complexity in medical practice and heightened safety requirements. Traditional medical education, based on direct clinical experiences, was constrained by the availability of cases and posed risks to patients due to medical errors. Developing innovative training methods that enable the practice of clinical skills in a safe and controlled environment became essential.

The problem solved in this study was the creation and validation of an efficient simulation-based training methodology that enhanced students' clinical competencies and satisfaction. This methodology demonstrated a positive impact on both theoretical and practical performance, providing a framework for its integration into the university curriculum. The implementation of simulation contributed to training in a safe environment, supported the accreditation process, and highlighted the potential of this approach to transform medical education.

Theoretical significance. The research reveals a significant shift in the paradigm of medical education, highlighting the inadequacy of ad-hoc educational sessions in clinical settings for refining physicians' skills. In this context, the study emphasized the need for curriculum standardization and the adoption of a systematic approach that incorporates deliberate practices, structured exercises, and rigorous outcome evaluations grounded in continuous feedback.

Practical applicability of the work. The effective implementation of the simulation component in various university-level study programs is essential. It aims to provide comprehensive and modern training for medical university students, facilitating their seamless integration into subsequent clinical activities during postgraduate residency. This is achieved by developing professional and communication skills, increasing self-confidence and decision-making abilities, and enhancing teamwork. Such an innovative methodology allows students to practice in controlled environments and receive constant feedback, significantly reducing medical errors. By applying this approach, graduates will be better prepared to face real clinical challenges, ultimately improving the quality of patient care. This will, in turn, enhance the overall quality of medical practice and increase patient safety, ensuring a higher educational standard and contributing to the general improvement of the healthcare system.

Priority scientific results submitted for defense:

1. A procedural framework for identifying needs and efficiently organizing simulation-based training in medical university education was developed and validated.
2. A significant improvement in students' practical competencies was demonstrated through the use of checklists developed as standardized assessment tools.
3. The positive impact of simulation-based training on theoretical knowledge was highlighted, as confirmed by the comparative analysis of pre-test and post-test results.
4. A high level of student satisfaction with the relevance and effectiveness of simulation-based training in medical education was determined.
5. Recommendations were formulated for the integrated, comprehensive, and efficient implementation of simulation-based training in the medical university curriculum.

Implementation of research results. As a result of the conducted research, the outcomes, including the procedural framework and developed evaluation tools, validated through innovation certificates, were applied within the University Center for Medical Simulation. These tools were utilized during the practical examination of the summer clinical internship, organized for 2nd- to 5th-year students from the Faculty of Medicine and Somatology, as well as for graduates of the Bachelor's program in General Nursing. The implementation of the Objective Structured Clinical Examination (OSCE), recommended by the World Federation for Medical Education and integrated into the University's Strategic Development Plan for 2021–2030, has strengthened the role of this evaluation method as a standard of excellence for assessing clinical competencies.

Approval of scientific results. The results obtained during the research were presented and discussed at the following scientific forums: The Second Conference of Simulations Applied in Medicine (Târgu Mureș, Romania, 2017); Annual Scientific Conference - University Days (Chișinău, Republic of Moldova, 2019); International Scientific Conference: Health, Medicine, and Bioethics in Contemporary Society: Inter- and Multidisciplinary Studies (Chișinău, Republic of Moldova, 2019); Virtual Annual Meeting of the Society for Simulation in Europe (2021); Scientific-Practical Conference with International Participation "Medical Simulation - A Look into the Future" (implementation of innovative technologies in higher medical education in Ukraine), online (Chernivtsi, Ukraine, 2021); Annual Scientific Conference "Research in Biomedicine and Health: Quality, Excellence, and Performance" (Chișinău, Republic of Moldova, 2022); International Conference on Simulation and Virtual Reality in Medicine, MediSim III (Târgu Mureș, Romania, 2023); Annual Scientific Conference "Research in Biomedicine and Health: Quality, Excellence, and Performance" (Chișinău, Republic of Moldova, 2023); 5th Interdisciplinary PhD Forum with International Participation (Kyustendil, Bulgaria, 2024); 3rd Edition of the International Exhibition of Innovation and Technology Transfer EXCELLENT IDEA (Chișinău, Republic of Moldova, 2024).

Publications related to the thesis. The thesis materials were reflected in 13 publications, including 2 single-author works, 2 articles in international journals, 2 articles in national journals, 2 articles in the proceedings of international scientific conferences, 6 theses in the proceedings of national and international scientific conferences, and 1 poster presented at an international scientific forum.

Summary of the thesis sections. The paper is written on a total of 181 pages in electronic format, of which 130 pages represent the main text. The structure of the paper includes the introduction, four chapters, a synthesis of the obtained results, conclusions, practical recommendations, and 26 appendices. The iconographic material consists of 37 figures and 26 tables. The scientific foundation of the paper is based on 97 bibliographic sources.

The study received favorable approval from the Research Ethics Committee of the Nicolae Testemițanu State University of Medicine and Pharmacy (no. 51, 12.04.2018).

Keywords: simulation-based training, medical education, professional training, practical skills, clinical competencies, patient safety, assessment, efficiency, university curriculum.

CONTENT OF THE THESIS

1. SIMULATION-BASED TRAINING AS A COMPLEMENTARY TOOL IN MEDICAL EDUCATION

This chapter provides an analysis of the specialized literature on the evolution and impact of simulation in medical training, ranging from early rudimentary simulators to the use of advanced virtual and augmented reality technologies. Simulation has become an essential component of medical education, offering a safe and controlled environment for practicing clinical skills without the risk of errors affecting real patients. Based on this synthesis, the educational and practical benefits of simulation are highlighted, grounded in theoretical frameworks such as Experiential Learning Theory and Andragogy, and methods such as high-fidelity mannequins and standardized patients. Although the implementation of simulation requires considerable resources, it improves clinical skills, enhances patient safety, and reduces medical errors. International best practice guidelines recommend immediate feedback and the integration of simulation into curricula to maximize educational effectiveness.

2. MATERIALS AND METHODS OF RESEARCH

2.1. General characteristics of the research

The research focused on evaluating the effectiveness of simulation-based training in university medical education at the Nicolae Testemițanu State University of Medicine and Pharmacy. This type of training is globally recognized as an innovative and essential tool in the education of medical students, aiming to bridge the gap between theoretical knowledge and real medical practice. The present study aimed to explore how simulation contributes to the development of students' theoretical and practical skills and to provide a methodological framework to support the implementation of this approach in university medical education.

The study was designed as an analytical, experimental, and sequential research project, employing a quasi-experimental design with pre-test and post-test comparisons. This approach allowed for the evaluation of the educational interventions' impact on students' clinical competencies through measurements taken both before and after participation in the simulation sessions. Given that the available conditions did not allow for complete randomization or strict experimental control, a quasi-experimental design was chosen. This approach proved to be pragmatic and effective in achieving the research objectives (Figure 1).

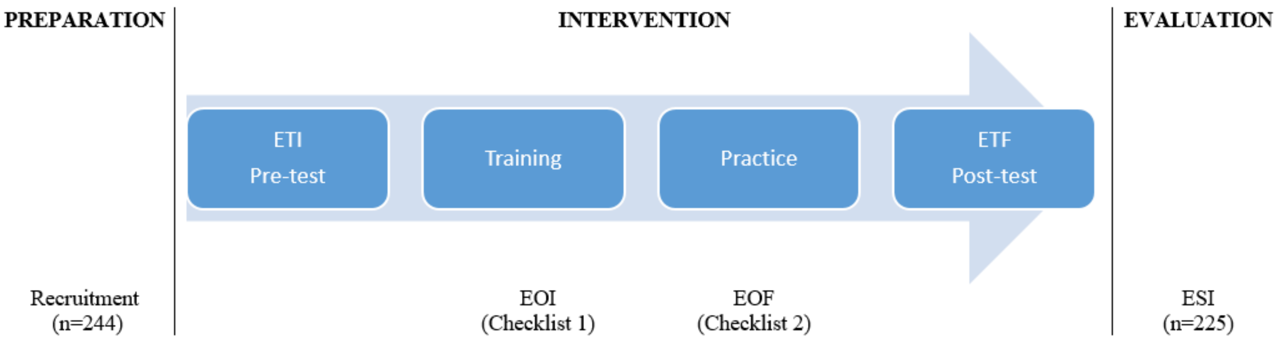

Figure 1. **Study design and stages**

An important aspect of the research was the calculation of the sample size. Parameters considered for this calculation included a 95% confidence interval and an 80% statistical power, taking into account an estimated difference of up to 30% between various clinical skills of students, such as medical procedures, patient triage, and parenteral medication administration. Based on these calculations, a sample of 35 participants was deemed adequate for detecting significant differences in students' competencies before and after the intervention. However, to provide a more comprehensive perspective, the study involved a total of 225 students, divided into six sets of practical skills (Table 1). Each set of skills was structured to cover essential medical competencies relevant to the university medical curriculum.

The participants were 2nd-, 3rd-, and 4th-year students, recruited through a public invitation. The participation criteria included enrollment in the Faculty of Medicine and voluntary consent to partake in the research. The simulation activities were conducted from February 2020 to November 2021 at the University Center for Medical Simulation of Nicolae Testemițanu State University of Medicine and Pharmacy. This intervention period allowed students to participate in structured training sessions organized based on the specific needs of each academic year.

Table 1. **List of skill sets and abilities**

Set	Abilities
Set 1: Preparation for medical procedures	01. Changing the medical mask
	02. Medical handwashing with soap and water
	03. Putting on/Taking off non-sterile gloves
	04. Putting on/Taking off a non-sterile gown
Set 2: Examination of adults in the triage room	05. Measuring pulse
	06. Measuring blood pressure
	07. Measuring body temperature axially with an electronic thermometer
	08. Adult anthropometry (measuring body weight, height, and BMI calculation)
Set 3: Parenteral medication administration	09. Administering a subcutaneous injection
	10. Administering an intramuscular injection
	11. Administering an intravenous injection
Set 4: Intravenous infusion administration	12. Setting up the infusion system
	13. Obtaining informed consent and administering intravenous infusion
Set 5: Operating room preparation	14. Medical hand disinfection with alcohol-based solutions
	15. Assisting in putting on a sterile gown
	16. Assisting in putting on sterile gloves
Set 6: Urinary catheterization for women and men (Foley catheter)	17. Putting on/Taking off sterile gloves
	18. Inserting/Removing the Foley catheter

The primary aim of the research was to develop and validate an efficient methodology for the application of simulation in university medical education, aimed at enhancing teaching quality and strengthening the management of the professional training process. An essential component of this methodology was the integration of clinical simulations as a fundamental part of the curriculum, providing students with a practical framework to apply theoretical knowledge in a controlled environment without risks to patients.

The research pursued four major objectives:

1. Development of the procedural framework – Establishing the necessity for and organizing simulation-based training at the university level, integrating clinical simulations as an essential part of the training program.
2. Evaluation of students' acquisition of practical skills – Using the observational method to assess their competencies based on standardized checklists.
3. Analysis of the impact of training on students' theoretical knowledge – Using pre- and post-training testing procedures to evaluate their progress.
4. Determination of student satisfaction – Measuring students' satisfaction levels regarding the simulation training experience using Likert-type questionnaires and other feedback methods.

At each stage of the research, the simulation methodology was designed to provide students with an immersive learning experience aimed at enhancing clinical skills, communication competencies, decision-making abilities, and emergency management. This training method allowed for the repeated practice of procedures in a safe and controlled environment, where errors became learning opportunities without posing risks to patients.

2.2. Data collection methods

In this study, a variety of methods were used, both traditional and innovative, tailored to the specifics of university medical education. The main instruments for data collection were written tests, checklists for assessing practical competencies, and satisfaction questionnaires.

Written tests were developed to evaluate students' theoretical knowledge before the educational intervention, initial theoretical evaluation (ETI), and after the intervention, final theoretical evaluation (ETF). These tests were structured to measure both the retention of information and its application in simulated clinical scenarios. Six tests were designed, each corresponding to a specific set of practical skills, featuring multiple-choice questions focused on topics relevant to simulation activities, such as hand hygiene, measurement of physiological parameters, and the correct administration of injections. For example, the tests included questions on medical handwashing, pulse and blood pressure measurement, as well as the correct techniques for performing subcutaneous, intramuscular, and intravenous injections.

Checklists were used to assess practical competencies during simulations, including a specific set of criteria for each medical procedure practiced. These provided instructors with objective and immediate feedback, enabling a detailed evaluation of each skill based on a binary system ("YES" or "NO"). Initial observational evaluations (EOI) were conducted at the beginning of the training to identify the initial level of competence, while final observational evaluations (EOF) were performed at the end of the simulation sessions to confirm the students' progress and competence in performing medical procedures in an integrated manner.

The checklists were detailed and structured into sets of practical skills, such as preparation for medical procedures, measurement of physiological parameters, intravenous infusion administration, and urinary catheterization. These tools ensured a systematic and rigorous evaluation of the essential competencies acquired during the training.

Satisfaction questionnaires were used to gather student feedback regarding their experience during the simulation sessions. Structured on a 5-point Likert scale, the questionnaires assessed students' perceptions of the utility and applicability of simulation-based training, as well as their overall satisfaction with the course delivery. Additionally, the questionnaire included questions about the practical applicability of the knowledge gained and suggestions for program improvement.

2.3. Analysis and interpretation of results

Data processing was performed using advanced statistical software, ensuring a rigorous and efficient process in line with the latest standards in medical research. The data were stored and processed using CAE LearningSpace®, Microsoft Excel 2013, R Studio, and SPSS 26. Each of these programs was utilized for specific aspects of data processing, from initial management to advanced statistical analyses. Specifically, CAE LearningSpace® was essential for analyzing data generated from educational simulations, while Excel was used for calculations and raw data management. SPSS 26 and R Studio were applied for data modeling and conducting complex statistical tests.

The statistical analysis techniques used included general data description through frequency distributions, means, and standard deviations, providing a clear view of trends and variations in the data. In the study, the Wilcoxon test for repeated measures was applied to compare scores obtained before and after the intervention, as this test is suitable for data with asymmetric distributions. The Wilcoxon test was complemented by the rank biserial correlation test to estimate the effect size, providing insights into the magnitude of observed changes, even when statistical significance was not apparent. A significance threshold of $p < 0.05$ was used to identify statistically significant differences between initial and final evaluations, thereby validating the intervention's effect.

The study results were presented through a series of tables and graphs comparing outcomes from the initial evaluation (ETI/EOI) and the final evaluation (ETF/EOF), highlighting the percentage of participants who demonstrated strong theoretical knowledge and correctly performed specific clinical procedures. These comparisons provided a clear visual representation of the students' progress, with statistical significance demonstrated through tests such as the Wilcoxon test and effect size measures.

The analysis of data from the satisfaction questionnaires was conducted using statistical measures such as mean, median, percentile, and standard deviation. These measures facilitated the evaluation of overall student satisfaction and their perception of the utility and effectiveness of the simulation program. Frequency and percentage analyses provided a clear view of students' agreement levels with various aspects of the educational intervention, while 95% confidence intervals ensured precise data interpretation and a measure of reliability.

Graphical representations, including boxplots and violin plots, illustrated the distribution of scores and individual variations, providing a detailed view of trends and deviations in the data. These visualizations helped clearly identify the changes in students' competencies following the educational intervention.

3. SIMULATION IN UNIVERSITY MEDICAL EDUCATION: DESIGN, IMPLEMENTATION, AND EVALUATION

This chapter focused on the efficient management of the professional training process by systematically integrating simulation tailored to the needs of each academic year. The aim was to optimize both the development of clinical competencies and the management of educational and logistical resources.

3.1. Development of the procedural framework by determining the need for and organizing simulation-based training at the university level

The primary objective of the research was to develop a structured procedural framework for the efficient implementation of simulation in university medical education, facilitating the development of clinical competencies and improving the quality of the educational process. **The procedural framework** was organized into four essential stages: planning and organization, implementation and execution, post-training analysis and adjustment, and continuous development (Figure 2).

The planning and organization phase represented the first stage of the process, aimed at thoroughly preparing the simulation sessions. Activities included identifying simulation topics by selecting and grouping practical skills, as well as determining appropriate methods. This process was facilitated by using skill lists and well-structured educational plans. Clear educational objectives were established and documented to ensure their relevance and suitability. A critical component was the development of scenarios and the configuration of the simulation environment, involving the creation of realistic clinical situations and the allocation of necessary resources. The program was piloted, and adjustments were made based on the feedback received.

The implementation and execution phase represented the practical stage of the procedural framework, actively involving participants in simulation activities. The process began with familiarizing students with the methodology used, ensuring a thorough understanding of the simulation components. The initial theoretical evaluation was conducted through written tests, followed by the assignment of participants to simulation stations for the efficient organization of activities. During the actual training, methods such as Peyton [35] were employed to facilitate interactive sessions, accompanied by formative assessments. At the end of this stage, clinical competencies and theoretical knowledge were reassessed through summative evaluations to measure student progress and the impact of the training.

Post-training analysis focused on collecting and interpreting feedback from both students and instructors. Participants' impressions were gathered through satisfaction questionnaires, which helped identify strengths and areas for improvement. Simultaneously, instructors analyzed the educational process and proposed adjustments to optimize future sessions.

The adjustment and continuous development phase represented the final stage, focusing on the ongoing improvement of simulation programs. Reports generated from feedback analysis and evaluations were used to adapt scenarios and educational methodologies. Additionally, workshops were organized for the continuous training of instructors, thereby enhancing their competence and adaptability. Resource optimization was supported through periodic audits, ensuring the efficient use of equipment and consumable materials.

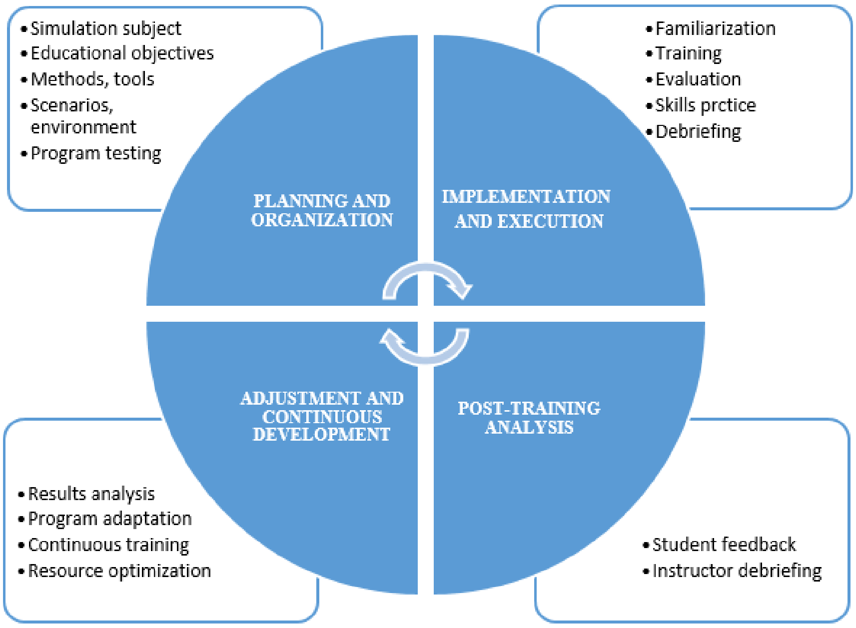

Figure 2. **Procedural framework**

3.2. Evaluation of students' acquisition of practical skills through the observational method, using checklists as an assessment tool

This subchapter explored the impact of a newly developed educational tool specifically designed to enhance clinical skills. The context of the educational intervention involved conducting evaluations in two essential stages: the initial observational evaluation (EOI) and the final observational evaluation (EOF). Both stages were used to assess students' clinical skills within a controlled clinical simulation environment. The EOI was conducted immediately after the training session, while the EOF took place after a period of time, allowing for the evaluation of progress in skill acquisition. The evaluations were based on standardized checklists that tracked each step of the practiced procedures, providing an objective framework for measuring student performance.

Regarding the structure and organization of skills, 18 essential practical skills for medical training were identified, grouped into six sets corresponding to specific clinical competencies. Each skill was trained and evaluated sequentially, ensuring that students completed all necessary steps within medical procedures. The sets encompassed skills ranging from handling personal protective equipment to medication administration techniques and patient condition assessment.

Skill evaluation was conducted at both a micro level (assessing each individual step of the procedures) and a macro level (integrating these steps into coherent clinical workflows), providing a comprehensive view of the competencies acquired by the students.

Within *Set 1 – Preparation for medical procedures*, essential skills such as changing a medical mask and washing hands with soap and water were included. The results for changing the medical mask (Figure 3) showed consistent improvement between the initial observational evaluation (EOI) and the final observational evaluation (EOF). Initially, 94.4% of students correctly handled the elastic loops, and by the EOF, this percentage increased to 100%. Similarly, the step of avoiding touching the face was performed correctly by 94.4% of students at the EOI, reaching 100% at the EOF, highlighting significant progress in most stages.

In the case of handwashing with soap and water, although performed well by most students, results for critical steps, such as hand rubbing, improved from 91.7% at the EOI to 97.2% at the EOF. However, closing the faucet with a paper towel remained a challenge for some students, with only moderate improvement as indicated by the Wilcoxon test (p = 0.069).

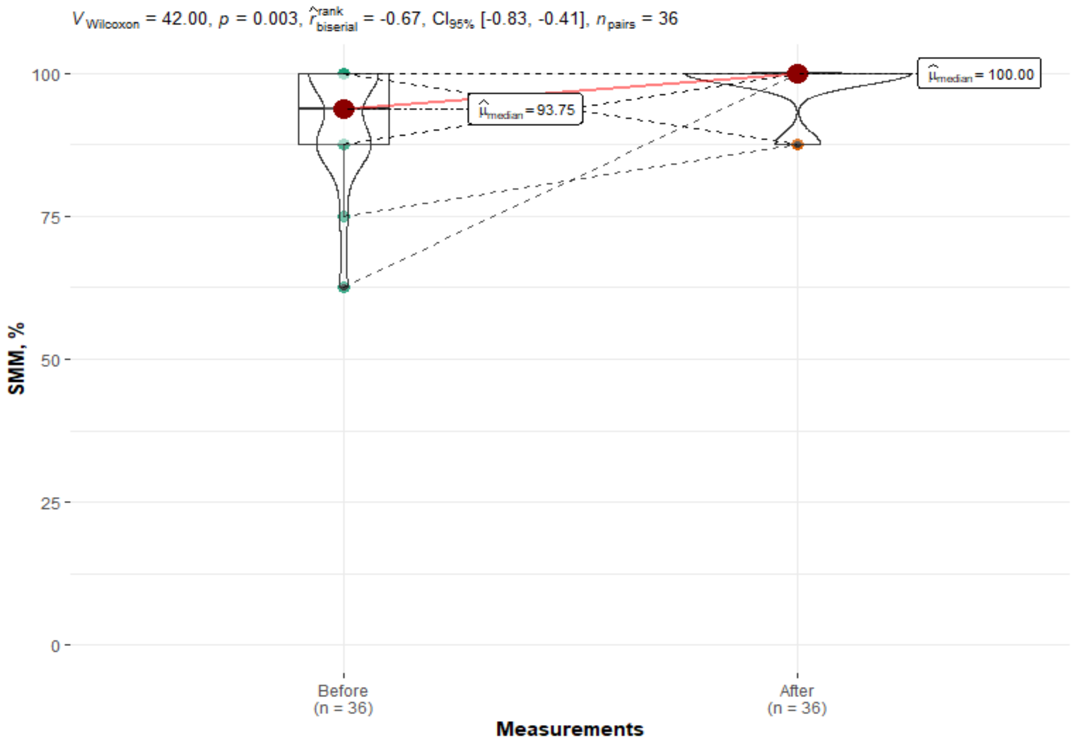

Figure 3. **The evolution of scores for the skill of changing a medical mask before and after the intervention**

For *Set 2 – Examination of adults in the triage room*, pulse measurement proved to be an excellently mastered skill. At the EOI, 100% of students correctly performed steps such as patient communication and counting pulses, and these scores were maintained at the EOF. The differences between the two evaluations were statistically insignificant (p = 0.484), indicating strong initial learning.

In contrast, blood pressure measurement was more challenging, particularly during the patient guidance step, where scores decreased from 100% at the EOI to 88.6% at the EOF. This decline suggests execution difficulties, and the Wilcoxon test indicated an insignificant difference (p = 0.777) with a small effect size.

Body Mass Index (BMI) determination and other anthropometric measurements yielded excellent results. At the EOI, 97.1% of students correctly performed the step of waiting for the final weight value, which increased to 100% at the EOF. The consistent performance is reflected by the absence of significant variations between evaluations. The Wilcoxon test showed no significant differences (VWilcoxon = 0.0, p = 0.346), but the effect size was large (-1.0), suggesting high practical relevance for future studies on larger cohorts.

For *Set 3 – Parenteral medication administration*, subcutaneous injection showed clear improvements between the EOI and EOF. For instance, in the needle withdrawal step, scores increased from 86.1% at the EOI to 94.4% at the EOF. However, maintaining cleanliness of the workspace remained a challenge, improving from only 52.8% at the EOI to 83.3% at the EOF. Although improvements were visually evident in the graphs, the Wilcoxon test indicated an insignificant difference (p = 0.087), with a moderate effect size (-0.35).

Intravenous injection, considered one of the most difficult skills, exhibited significant improvement in vein stabilization, increasing from 55.6% at the EOI to 97.2% at the EOF. Similarly, for steps like inserting the needle into the vein, scores rose from 66.7% at the EOI to 94.4% at the EOF, with a moderate effect size (-0.33).

Set 4 – Intravenous infusion administration was one of the most well-mastered skill sets. Setting up the infusion system (Figure 4) achieved scores of 100% in most steps at both EOI and EOF, demonstrating consistent progress. The differences between evaluations were statistically significant (p = 0.001), with a large effect size (-0.89), indicating a strong impact of the training.

However, obtaining informed consent showed variable results. While most steps, such as verifying the patency of the cannula, were performed correctly by 100% of students, the step of recording the infusion start time dropped from 87.5% at the EOI to 77.5% at the EOF. This decline was not statistically significant (p = 0.343), with a small effect size (0.25).

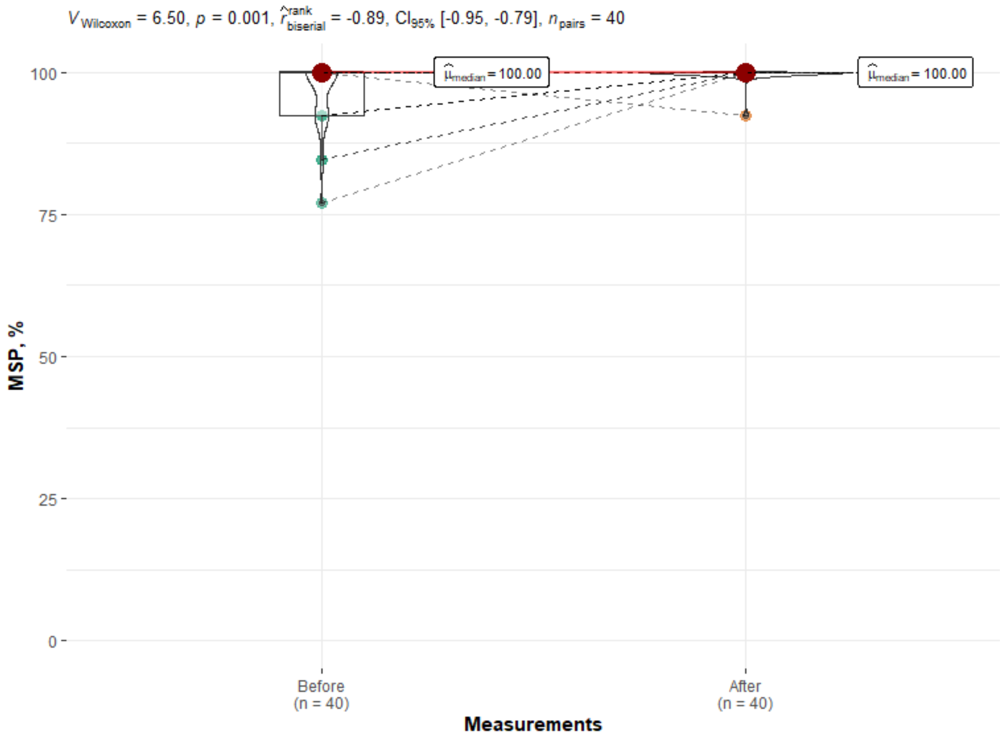

Figure 4. **The evolution of scores for the skill of setting up the infusion system before and after the intervention**

In *Set 5 – Preparation for the operating room*, medical handwashing with alcohol-based solutions demonstrated excellent results. Most steps were performed correctly in over 97% of cases, with no major differences between the EOI and EOF. The Wilcoxon test showed minimal significance ($p = 0.001$), but the effect size was negligible (0.02).

For assisting with the donning of a sterile gown, improvement was observed between the EOI and EOF, particularly in the declarative handwashing step, where scores increased from 87.2% at the EOI to 97.4% at the EOF. Statistical differences were not significant ($p = 0.583$), but the effect size was moderate (-0.33).

For *Set 6 – Urinary catheterization for women and men (Foley catheter)*, scores demonstrated significant improvement between the EOI and EOF, similar to those observed in previous sets. In preparing materials and performing handwashing, the correctness percentage increased from 75% at the EOI to 94.4% at the EOF.

For the step of inserting the catheter in women, scores rose from 69.4% at the EOI to 91.7% at the EOF, indicating clear progress in mastering the procedure. In male catheterization, where the initial correctness percentage for catheter lubrication and genital manipulation was 66.7%, an increase to 88.9% was observed at the EOF.

For the final stages, such as inflating the balloon and securing the catheter, the percentage increased from 83.3% at the EOI to 97.2% at the EOF. Differences between the EOI and EOF were statistically confirmed, with the Wilcoxon test showing moderate significance ($p = 0.005$) and a substantial effect size (-0.65), highlighting the significant impact of the training on student performance.

4. EFFICIENCY OF SIMULATION-BASED TRAINING IN UNIVERSITY MEDICAL EDUCATION

This chapter analyzes the impact of simulation on medical education by comparing students' performance before and after the intervention. The methodology included pre- and post-training tests to evaluate progress and Likert-scale questionnaires to measure student satisfaction, contributing to the continuous optimization of educational programs.

4.1. Analysis of the impact of training on students' theoretical knowledge through the application of pre- and post-training testing procedures

The study evaluated the impact of training on students' theoretical competencies by analyzing their progress through pre-training testing (ETI) and post-educational intervention testing (ETF). Six sets of essential skills for medical training were examined, each undergoing a rigorous evaluation to measure significant changes in students' knowledge and practical abilities.

In the preparation for medical procedures, significant improvements were observed in students' skills, such as changing a medical mask and handwashing. Initially, only 58.3% of students answered questions about changing a mask correctly, but this percentage increased to 97.2% after the educational intervention. Similarly, the results for handwashing showed an increase in the median score from 50% to 80%. Wilcoxon statistical tests confirmed significant differences ($V = 5.5$, $p = 0.013$), with a considerable effect size, emphasizing the positive impact of the training.

In the adult examination in the triage room set, students demonstrated remarkable progress in measuring pulse and blood pressure (Figure 5). After the training, the success rate for pulse measurement reached 100%, up from 71.4% in the pre-test, and blood pressure was measured correctly by all students, compared to 94.3% initially. Statistical analysis revealed significant differences for both skills (V = 0.0, p = 0.001), with the effect size estimated at -1.0, indicating a substantial improvement.

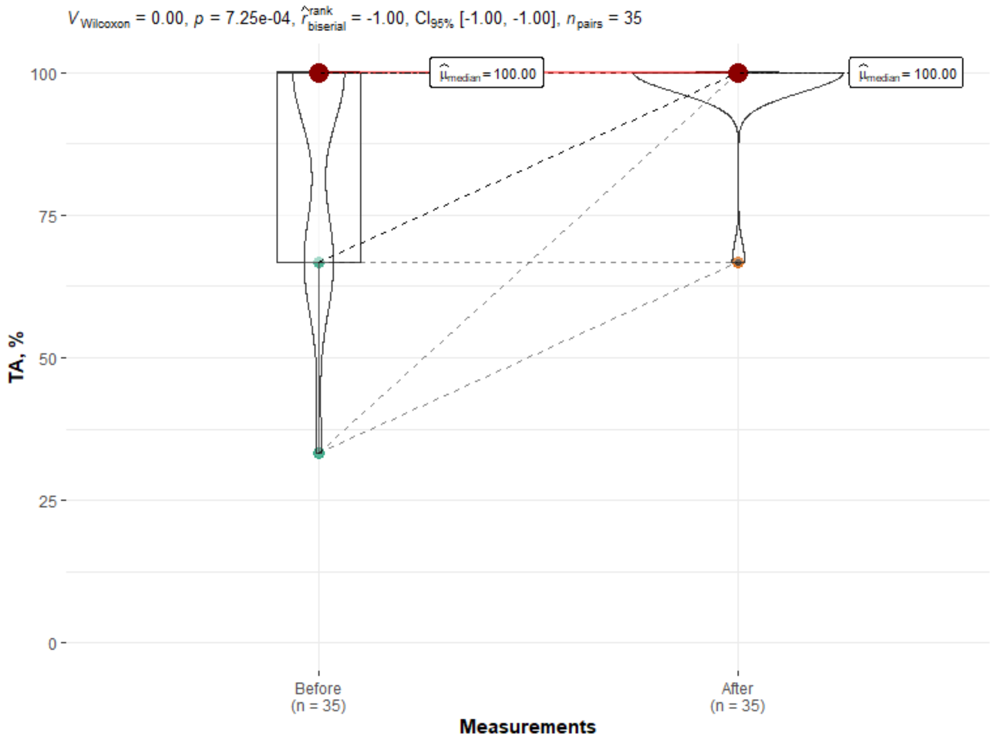

Figure 5. **The evolution of pre-/post-test results for the skill of blood pressure measurement**

For the parenteral medication administration set, initial results were modest. Only 25.6% of students answered questions about subcutaneous injection correctly, but this percentage increased to 74.4% after the training. Similarly, for intravenous injection, the percentage rose from 44.2% to 81.4%. The differences were statistically significant (V = 12, p < 0.001), with a very large effect size, indicating a significant impact of the educational intervention.

The set for intravenous infusion system setup also showed remarkable improvements. The success rate increased from 72.5% in the pre-test to 100% in the post-test. However, other skills, such as obtaining the patient's informed consent, did not exhibit the same level of improvement, with differences being statistically insignificant (V = 156.0, p = 0.543).

The operating room preparation set included fundamental skills such as handwashing with alcohol-based solutions (Figure 6) and donning sterile gloves, both of which showed substantial improvements. Handwashing increased from an average of 40% in the pre-test to 80% in the post-test, while donning sterile gloves improved from 50% to 100%. Wilcoxon tests indicated significant differences (V = 7.50, p < 0.001), with a large effect size, confirming the effectiveness of the training.

For the urinary catheterization set, students' skills in inserting and removing the Foley catheter improved significantly. The frequency of correct responses increased from 57.9% to 89.7% after the intervention, and donning sterile gloves improved from 46.2% to 74.4%. These differences were confirmed as significant (V = 42.5, p = 0.008), with the effect size indicating meaningful progress both statistically and practically.

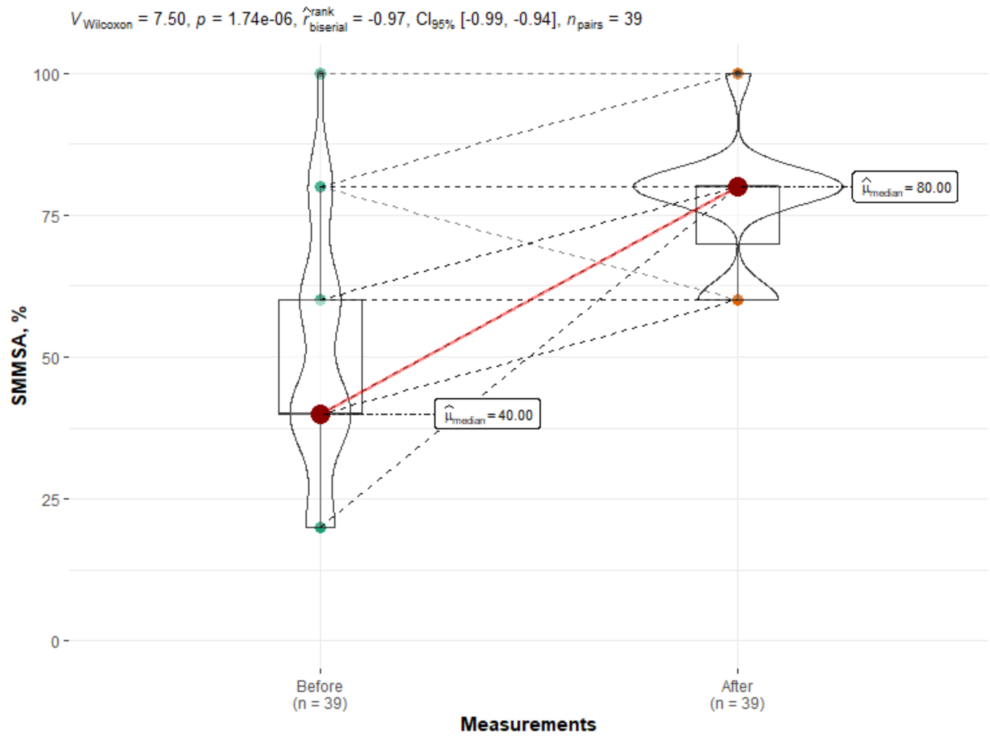

Figure 6. **The evolution of Pre-/Post-Test Results for the Skill of Medical Handwashing with Alcohol-Based Solutions**

4.2. Determination of student satisfaction with the applied components of simulation-based medical training

The subchapter analyzed students' satisfaction with medical simulation training, essential for developing practical skills and optimizing professional education. The questionnaire, structured on a 5-point Likert scale (from "Strongly Disagree" to "Strongly Agree"), included three sections: mandatory quantitative questions (Section I), optional qualitative questions (Section II), and an open section for suggestions (Section III). Sections I and III assessed post-intervention satisfaction, while Section II reflected students' prior experiences.

Section I, dedicated to evaluating student satisfaction regarding the efficiency and relevance of simulation-based training, analyzed their opinions on various aspects of the medical training process. Regarding their perception of theoretical knowledge before the course, results indicated that 28.9% of students (95% CI: 23.3% - 35.1%) remained neutral, while 21.8% (95% CI: 16.8% - 27.5%) somewhat agreed that they possessed sufficient theoretical knowledge prior to starting the training.

Regarding practical skills before the course, 30.7% of students (95% CI: 24.9% - 36.9%) reported significant deficiencies, acknowledging gaps in their practical preparation. Additionally, only 7.6% (95% CI: 4.6% - 11.6%) stated that they had a high level of practical readiness prior to the simulation-based training.

Regarding the effectiveness of simulation for professional training, 85.8% of respondents (95% CI: 80.8% - 89.9%) strongly agreed that simulation was effective in preparing them for future medical activities.

A crucial aspect, assessed through the question on motivation for learning and professional development, revealed that 91.6% of students (95% CI: 87.4% - 94.7%) acknowledged that simulation-based training motivated them to learn more and pursue professional development.

Regarding the objectivity of performance evaluation, 93.3% of students (95% CI: 89.5% - 96.1%) agreed that the assessment of their performance during the study was objective and fair.

Personal expectations were also analyzed, with 87.6% of students (95% CI: 82.8% - 91.4%) stating that the training fully met their expectations.

Furthermore, nearly unanimously, 98.7% of respondents (95% CI: 96.5% - 99.6%) agreed that simulation deserves to be promoted as an educational method.

The preference for simulation-based training was confirmed by 96.9% of students (95% CI: 94.0% - 98.6%) who indicated they would choose to participate in such a course again in the future.

The importance of simulation in developing practical skills was acknowledged by 95.1% of students (95% CI: 91.7% - 97.4%) as essential in preparing them for medical practice before working directly with patients.

Additionally, 94.0% of respondents (95% CI: 89.8% - 96.7%) stated that simulation should be used for learning all practical skills, highlighting the broad utility of this method.

Another important aspect was overcoming psychological barriers to performing medical procedures, with 80.9% of students (95% CI: 75.4% - 85.6%) agreeing that simulation helped them address these challenges.

Regarding the duration of the training, 76.4% of students (95% CI: 70.6% - 81.6%) considered it to be sufficient.

Regarding the number of repetitions of practiced maneuvers, 79.6% of students (95% CI: 73.9% - 84.4%) stated that they had sufficient opportunities to repeat procedures during the simulation.

After completing the training, 75.1% of students (95% CI: 69.2% - 80.4%) reported that they had acquired enough theoretical knowledge to perform medical interventions correctly.

Finally, 73.3% of respondents (95% CI: 67.3% - 78.8%) stated that they had gained sufficient practical knowledge to correctly perform medical interventions.

The descriptive statistics for overall satisfaction (Table 2) indicated that students' satisfaction levels ranged from 60% to 100%, with an overall mean of 96.5% (95% CI: 95.8% - 97.2%). The standard deviation was 5.2%, suggesting relatively low variability in student responses. The median, at 98.3% (95% CI: 98.3% - 100%), reflects that half of the respondents reported at least this level of satisfaction. One-quarter of students reported a minimum satisfaction level of 95%, while three-quarters of respondents achieved a maximum satisfaction level of 100%.

Table 2. **Descriptive Statistics of Questionnaire Results on Satisfaction**

Satisfaction	Mean	96,5
	95,0% Lower CL for Mean	95,8
	95,0% Upper CL for Mean	97,2
	Median	98,3
	95,0% Lower CL for Median	98,3
	95,0% Upper CL for Median	100,0
	Maximum	100,0
	Minimum	60,0
	Standard Deviation	5,2
	Percentile 25	95,0
	Percentile 75	100,0

In Section II, which evaluated the application of skills learned prior to the educational intervention and their impact on patients, the results were significant. Regarding the application of theoretical skills in practice, 23.9% of students (95% CI: 18.0% - 30.6%) reported difficulties in fully implementing them, while 76.1% (95% CI: 69.4% - 82.0%) stated that they successfully applied the skills learned.

In terms of adverse effects on patients, only 8.0% of respondents (95% CI: 4.6% - 12.6%) reported negative effects, while an overwhelming majority, 92.0% (95% CI: 87.4% - 95.4%), confirmed that no such effects occurred as a result of applying their skills.

The suggestions and comments from Section III highlighted students' aspirations regarding simulation-based medical training. Among the proposals were extending the duration of practical courses and organizing them more frequently, preferably twice a month or even weekly. Students also suggested diversifying the procedures practiced, such as including skills like catheter placement and oxygen therapy administration.

Another significant suggestion was the mandatory integration of simulations into the faculty curriculum, particularly before the summer internship, to better prepare students. Additionally, students expressed a desire for more open access to the simulation center, akin to laboratories in other fields, to allow for regular practice of their skills.

GENERAL CONCLUSIONS

1. The implementation of simulation in the medical university curriculum is crucial for training competent and confident professionals capable of managing real clinical challenges. Research has shown that simulation enhances traditional learning by providing an integrated and adaptable educational experience in a controlled and safe environment. It facilitates deep experiential learning through the faithful recreation of clinical scenarios, ranging from basic procedures to complex emergency situations. The systematically organized procedural framework ensures the continuous development of clinical competencies, progressing from fundamental skills to complex procedures as students advance through their years of study. Logistics involve the appropriate setup of simulation spaces, necessary equipment, and consumable materials, which are essential for authentic and effective learning.

2. The evaluation of the impact of simulation-based training on students' clinical skills, using a standardized assessment checklist, highlighted significant improvements and sustained high performance levels. The median results of initial and final assessments indicate the high effectiveness of simulation in strengthening essential clinical competencies. Skills such as changing medical masks (from 93.75% to 100%), medical handwashing (maintained at 100%), and donning and doffing protective equipment (consistent at 100%) demonstrated maximum performance. Significant improvements were observed in the administration of injections: subcutaneous (from 80% to 86.67%), intramuscular (from 71.43% to 85.71%), and intravenous (from 82.35% to 88.24%).

3. The evaluation of the impact of simulation-based training revealed significant improvements in students' theoretical knowledge. The pre- and post-test analysis showed notable increases across most assessed skills. For instance, the frequency of correct responses for changing medical masks increased from 58.3% to 97.2%, while medical handwashing demonstrated a median improvement from 50.0% to 80.0%. Skills such as donning and doffing sterile gloves and inserting a Foley catheter also showed significant advancements. Consistent performance, such as the increase from 62.0% to 75% for measuring pulse and blood pressure, with correct responses in both tests, indicates familiarity with the theoretical aspects of these topics. However, this does not necessarily imply that practical skills have reached the same maximum level.

4. Students' satisfaction with simulation-based training was assessed in the study using a 5-point Likert scale questionnaire. The results demonstrated a high overall satisfaction level, with an average of 96.5% and a median of 98.3%, reflecting a positive perception of this method. Approximately 85.8% of students found simulation-based training effective for their professional development, and 91.6% stated that it motivates them to pursue further professional growth. Simulation was highly valued for its objective assessment process (93.3%) and its role in fostering student advancement (98.7%). Additionally, 94.0% of students considered simulation essential for learning practical skills, with 80.9% reporting that it helped them overcome psychological barriers. However, 23.9% of students reported difficulties in applying theoretical knowledge to practice, highlighting the need for more robust educational support. Students also suggested expanding and diversifying simulation courses, emphasizing the importance of integrating this method into the core curriculum.

5. The research led to the development of complex and practical recommendations for the implementation of medical simulation training at the university level, detailed in the "Recommendations" section of the thesis. Measures identified include the systematic integration of simulation into the university curriculum, the use of advanced technologies, the development of specialized infrastructure, and the continuous training of teaching staff.

RECOMMENDATIONS

For the Ministry of Education and Research:

1. *Adoption of guidelines for simulation-based training.* Defining pedagogical standards for the use of high- and medium-fidelity simulators, including the assessment of clinical competencies and other practical skills, and integrating simulation as a central element in university-level medical education programs.

2. *Fostering research in simulation-based education.* Providing grants for research projects investigating the effectiveness of simulation in education, its impact on clinical competencies, and the reduction of medical errors, as well as establishing a national framework for disseminating the results of such research.

3. *Establishment of national advisory councils.* Creating working groups composed of experts in education, simulation, and public policy to support the development and adoption of modern educational strategies.

For the Ministry of Health:

1. *Development of a national policy on the use of simulation in medical education.* Creating a regulatory framework to standardize the use of simulation in university-level medical education and continuing training programs, including regulations for the accreditation of simulation centers and clear criteria for infrastructure, equipment, and qualified personnel.

2. *Promoting simulation in public policies focused on patient safety.* Integrating simulation as a mandatory standard in the training of healthcare professionals and including it in the accreditation and certification criteria for medical personnel and institutions.

3. *Allocation of funds for the development of simulation centers.* Investments in high-fidelity equipment, dedicated spaces, and innovative technologies such as virtual and augmented reality must be supported by a funding mechanism that covers the operational and maintenance costs of simulation centers.

4. *Collaboration with international partners to access financial assistance programs.* Seeking support from international organizations for the development of simulation-based educational infrastructure.

5. *National program for training simulation educators.* Organizing courses for university faculty and trainers involved in simulation-based education, aimed at creating a body of experts to support the implementation and monitoring of educational standards.

6. *Partnerships between medical education institutions and hospitals*. Facilitating the use of simulation centers for the practical training of students and medical residents, as well as promoting the exchange of best practices between institutions at both national and international levels.

7. *Continuous update of medical personnel competencies.* Incorporating simulation as a core method in continuing education programs for medical personnel to enhance clinical skills, reduce errors, and improve patient safety.

8. *Promoting the benefits of simulation in medical education and other fields.* Organizing public events, conferences, and national campaigns to highlight the positive impact of simulation on professional training.

For the "Nicolae Testemițanu" State University of Medicine and Pharmacy and the "Raisa Pacalo" Center of Excellence in Medicine and Pharmacy:

1. *Strengthening simulation infrastructure.* Modernizing and expanding existing simulation centers to cover a wider range of procedures and clinical scenarios, including the use of advanced technologies such as virtual and augmented reality.

2. *Integration of simulation into the curriculum.* Developing curricula that incorporate simulation as a central teaching method, progressively applied throughout the study cycles, and establishing mandatory modules for each medical specialty, ranging from fundamental skills to complex interdisciplinary scenarios.

3. *Faculty development.* Organizing training programs for academic staff, including certifications in facilitating simulation-based training and managing complex scenarios, as well as encouraging their participation in international conferences and exchange programs to adopt best practices in simulation use.

4. *Student assessment through simulation.* Implementing simulation as a primary method for evaluating the clinical competencies of students and residents, by developing standardized tools to measure both technical skills and non-technical skills such as communication and decision-making.

5. *Interdisciplinary and multidisciplinary collaboration.* Developing simulation programs that involve students and residents from various medical, pharmaceutical, and paramedical specialties, including complex emergency simulations with mixed teams of doctors, nurses, pharmacists, and paramedics, to enhance teamwork in interdisciplinary settings.

6. *Promoting research in medical simulation.* Establishing a dedicated structure for research in simulation-based medical education to explore new methods, evaluate its impact on educational outcomes, and encourage dissemination through publications in specialized journals and the organization of scientific events.

7. *Establishing strategic partnerships.* Collaborating with universities and simulation centers regionally and internationally to exchange best practices and develop joint projects, while involving private and governmental institutions to support the logistics and funding of simulation centers.

8. *Monitoring and optimizing the educational process.* Implementing a continuous monitoring system for the use of simulation in education, including the evaluation of feedback

from students and faculty, and periodically adjusting simulation programs based on assessment results and practical needs in the medical field.

9. *Promoting simulation in continuing education.* Organizing simulation-based courses and workshops for the continuing education of medical and paramedical staff, including the integration of simulation into training programs for emergency preparedness and disaster management, to enhance the quality of medical practice.

For Academic staff:

1. *Continuous professional development.* Participating in courses and workshops focused on the use of simulation methods, including scenario facilitation, performance assessment, and providing feedback, as well as obtaining national or international certifications in simulation-based education to ensure professional excellence.

2. *Integrating simulation methods into teaching plans.* Designing simulation-based educational activities aligned with curricular objectives and required clinical competencies, and using them as a teaching method to complement theoretical lessons, ensuring a balance between theoretical knowledge and practical application.

3. *Standardizing scenarios and assessment.* Collaborating with colleagues to develop standardized simulation scenarios tailored to students' educational needs, and using assessment tools with checklists and clear rubrics to ensure objective evaluation of clinical competencies.

4. *Fostering experiential learning.* Designing realistic clinical scenarios, ranging from basic procedures to complex emergencies, and encouraging students to reflect on their experiences through guided questions and post-simulation debriefing discussions.

5. *Interdisciplinary collaboration.* Engaging in interdisciplinary simulation sessions involving students and faculty from various disciplines to develop teamwork and communication skills.

6. *Promoting a culture of patient safety.* Emphasizing the importance of adhering to patient safety protocols and preventing medical errors during simulation sessions by designing scenarios focused on risk identification and making rapid, safe decisions.

7. *Utilizing modern technologies.* Gaining proficiency in the use of high-fidelity simulators, virtual reality, and augmented reality in the educational process, as well as exploring innovative methods such as hybrid simulations that combine technology with human interaction.

8. *Evaluation and self-reflection.* Continuously monitoring one's performance as a simulation facilitator, identifying areas for improvement, and seeking feedback from students and colleagues to adapt teaching methods to educational needs.

9. *Contribution to research and innovation.* Participating in research projects on the impact of simulation on educational outcomes and patient safety, as well as publishing case studies and articles on simulation activities to contribute to the development of specialized literature.

10. *Managing simulation logistics.* Ensuring the optimal use of available resources, such as simulators, equipment, and consumables, through detailed logistical planning that includes time allocation for setup, execution, and debriefing of each simulation session.

11. *Cultivating a supportive attitude toward students.* Encouraging active participation and the expression of concerns or challenges faced during simulations by creating an empathetic and inclusive learning environment that fosters confidence and professional skill development.

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ROMANCENCO Andrei

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