

Recommendations for the design of a mobile application for medical simulations

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Abstract— Currently, medical students' learning involves using digital applications that allow them to understand human body functionalities and perform various manipulations as part of their education. The objective of this work is to propose 8 recommendations for the design of a mobile application for medical simulations. The recommendations are based on the analysis of 24 research studies related to medical simulations. The recommendations were divided into two categories: (i) Recommendations for the design of a mobile application, and (ii) Recommendations for the use of Artificial Intelligence models. For a better understanding, an illustrative example of the design of a mobile application with the proposed recommendations is shown. Furthermore, an early validation with 18 subjects medical students provide initial empirical evidence, demonstrating a high perceived usefulness and ease of use of an application built on these recommendations. These recommendations aim to provide a foundational framework for developers to design effective mobile medical simulation applications, serving as a basis for future empirical validation

Keywords—recommendations, mobile application, medical simulations, artificial intelligence.

I. INTRODUCTION

The study of medicine is essential for the development of society, as it improves people's quality of life. For this reason, it is necessary for professionals to acquire skills that enable them to understand, diagnose, and treat diseases effectively [1]. The training of medical students should be encouraged by educators whose theories must be linked to the real-world practice of clinical cases [2].

During medical students' educational training, a concept called medical simulations is introduced, consisting of using technological tools to replicate a real clinical scenario. Medical simulations enable students to carry out cost-effective learning in safe and controlled environments[2] [3].

Medical simulation was first introduced in the 1960s with the use of a mannequin for cardiopulmonary resuscitation practice, called Resuci Anne [3]. This resource proved effective in reinforcing the practical skills of medical students, which encouraged the adoption of simulations in the educational field. As technology has advanced, medical simulations have incorporated increasingly sophisticated tools, among which artificial intelligence (AI) stands out, significantly transforming the teaching and evaluation possibilities in medical training [4]. In Peru, the field of medical simulation has shown considerable growth, with increasing interest from educational and health institutions to implement this type of learning method. However,

infrastructure limitations in the country and the high cost of equipment hinder the ability to meet demand, highlighting the need for more accessible solutions [5].

Given the growing demand for accessible medical simulation tools and the potential of mobile technology, this study seeks to answer: What are the key design recommendations for developing mobile applications that support medical simulations? The contribution of this work is the proposal of a set of eight recommendations for designing mobile applications for medical simulations. The proposed recommendations are based on the analysis of 24 research studies related to the use of medical simulations. The recommendations are divided into 2 categories: (i) recommendations for designing a mobile application, explaining different types of tools for app design, gamification elements, learning approaches, and use of mobile devices; and (ii) recommendations for the use of AI models, indicating which AI models can be used according to other developed works. These recommendations for mobile application design are aimed at medical students. In addition, it shows an illustrative example of the design of a medical simulation application based on the proposed recommendations.

The remainder of the paper is structured as follows: Section 2 presents a literature review on the development of medical simulation applications, including those that integrate artificial intelligence. Section 3 describes the proposed recommendations for designing medical simulation applications based on artificial intelligence. Section 4 shows an illustrative example based on recommendations proposed. Section 5 shows an early validation. Finally, Section 6 addresses the study's conclusions, limitations, and recommendations for future research.

II. RELATED WORKS

In this section, we review studies related to the development of medical simulation applications for medical students. The review is conducted through a Targeted Literature Review (TLR), a non-systematic and informative review that selects only significant references to minimize bias. This approach was chosen due to the exploratory nature of this study, aiming to synthesize existing design patterns and technological integrations for mobile medical simulation applications, rather than conducting a comprehensive systematic review of all empirical evidence.

The proposed recommendations for developing medical simulation applications are based on research collected from the PubMed bibliographic repository (see <https://pubmed.ncbi.nlm.nih.gov/>). The search string used in

this study is as follows: ("medical simulation" AND "mobile application" OR "artificial intelligence" OR "clinical training" OR "medical education").

The inclusion criteria are: (1) studies focusing on the design, development, or use of mobile applications in medical education, (2) topics that directly involve the application of simulation for medical or health sciences training, and (3) applications or tools aimed at practical training for university medical students or health professionals

The exclusion criteria are: (1) studies unrelated to medical simulation, mobile applications, or artificial intelligence in a medical education context (2) studies addressing general education, patient-facing health apps, or medical topics not related to university-level training and (3) Existing literature reviews, systematic reviews, or meta-analyses were excluded to avoid double-counting sources, though they were used to identify primary research. The initial search yielded 34 scientific articles; after applying the established criteria, 8 relevant articles were selected. These studies were organized into two categories: (i) Use of simulation in mobile applications for medical education and (ii) Integration of artificial intelligence models in medical simulations.

A. Development of Medical Simulation Applications

Roncal-Belzunce et al. [6] developed Optipharm, a gamified e-learning tool designed for health sciences students, focused on improving their skills in managing polypharmacy in geriatric care. The study examines Optipharm's usability and impact on pharmacological education by simulating clinical scenarios where users assume the role of health professionals in multidisciplinary consultations.

Prochazkova et al. [7] introduced an interactive e-learning application designed to teach medical molecular genetics using a problem-based approach with gamification elements. The application guides students through 13 tasks that simulate the diagnostic process of a hereditary disease.

Sundareswaran et al. [8] developed a gamified serious game for teaching medical physiology to Generation Z students, addressing both learning and assessment in this discipline. The application uses an accessible interface that allows students to interact with scenarios related to cardiovascular and neuromuscular physiology. The results show high acceptance among students, who emphasized the value of gamification in improving comprehension of complex concepts and promoting active learning.

Hu et al. [9] developed the role-playing game "IEMT Training Game" to train newly incorporated nurses in international emergency medical teams (IEMT), focused on enhancing their disaster response skills. In the game, participants assume the role of IEMT nurses, assessing and treating patients in a virtual disaster simulation environment.

In summary, the reviewed studies highlight a trend toward using gamified simulations to optimize learning in clinical and scientific contexts. Gamified e-learning platforms facilitate the acquisition of knowledge and skills in complex areas, enhancing user experience and learning satisfaction.

B. Use of Artificial Intelligence in Medical Simulation Applications

Noroozi et al. [10] developed LapBot Safe Chole, a mobile educational game for training students and medical professionals in safely performing laparoscopic

cholecystectomy. The application uses artificial intelligence to provide real-time feedback on safe and hazardous dissection zones, helping users improve intraoperative decision-making.

Hasoomi et al. [11] developed a virtual reality (VR) simulation educational application for preclinical radiotherapy students, integrating artificial intelligence (AI) to enrich the learning experience. The application simulates a treatment environment with a linear accelerator (LINAC), allowing students to practice patient positioning, use immobilization devices, and configure treatment fields. The AI enables the creation of virtual characters that interact in real time, responding to students' questions and offering detailed explanations on complex radiotherapy concepts.

Nagaraj et al. [12] developed AI models for video assessment and feedback in training suturing and knot-tying skills for medical students. Students performed an interrupted suture and submitted videos for assessment. The AI models, based on convolutional neural networks, were trained to identify errors in instrument handling and knot-tying, achieving accuracies of 89% and 91%, respectively.

Mirchi et al. [13] developed the Virtual Operative Assistant, an educational tool powered by explainable AI, designed for simulation-based training in surgical procedures. This platform uses a support vector machine (SVM) model to classify and assess user performance in a virtual reality brain tumor resection task, distinguishing between novice and expert participants.

In summary, the studies reviewed in this category demonstrate how simulation technologies and artificial intelligence are transforming medical education in surgical and complex clinical procedure environments. Educational applications that use AI provide real-time guidance, as well as AI models to analyze and assess procedural skills. This emphasis on AI-enhanced feedback underscores its potential to deliver detailed, specific information that supports students in mastering complex medical skills.

III. DEFINITION OF RECOMMENDATIONS FOR APPLICATION DESIGN

This section presents a set of 8 recommendations for designing mobile simulation applications aimed at medical students. The recommendations were formulated based on the analysis of 24 research studies related to medical simulations. Each recommendation addresses key elements that should be included in the design, such as: (i) incorporating gamification techniques, (ii) using mobile devices to run simulations, (iii) implementing large language models (LLMs) in medical contexts, (iv) applying artificial intelligence to provide feedback, among others. Each recommendation is assigned a prefix "R" followed by a sequential number, such as R1, R2, R3, etc. Below are the 8 recommendations for designing medical simulation applications.

A. Recommendations for the Design of a Medical Simulation Application

R1: The analyzed studies cover the use of gamification techniques in the design of medical education and simulation applications, as in: (i) Taj et al. [14], who use a modified version of a game simulating medication adherence through interactive reminders. Results showed that reminders effectively increased adherence. (ii) Nemirovsky et al. [15] present the interactive platform SICKO, designed to train

surgeons in decision-making during realistic clinical scenarios. The platform uses a level structure where users must manage multiple patients, receiving feedback through a scoring system. (iii) Hope et al. [16] explored the virtualization of a pharmacy simulation due to the COVID-19 pandemic. The game incorporates tasks with a competitive focus, a continuous scoring system, and incentives for good practices.

In conclusion, it is recommended to use gamification elements such as reminders, level and scoring systems, representation of real concepts in the form of game elements, goals, and rewards to promote effective learning in critical situations.

R2: The studies analyzed in this section explore the use of simulations with a problem-based learning (PBL) approach. (i) Peng et al. [17] studied the effects of combined simulation and PBL learning in joint surgery teaching. Results showed that this approach significantly improved theoretical knowledge, clinical skills, and student satisfaction compared to traditional methods. (ii) Peng et al. [18] investigated the use of virtual simulation with PBL for pediatric medical students. Students in the experimental group demonstrated greater academic competence, better pediatric communication skills, and a high degree of satisfaction. (iii) Xie et al. [19] applied a virtual simulation platform combined with PBL for teaching clinical biochemistry during the pandemic. This hybrid method allowed for better knowledge retention, greater mastery of practical skills, and the development of critical clinical thinking compared to traditional learning.

In conclusion, these studies recommend using a PBL approach combined with virtual simulation, as this method allows students to reinforce critical thinking and practical skills.

R3: The analyzed studies focus on the use of medical simulation applications on mobile devices, such as: (i) Dsouza et al. [20] developed a smartphone-based skin simulation model for medical education, combining a translucent elastomer layer with a mobile application that corrects optical distortions in images of skin lesions, providing a realistic visual and tactile representation of the skin. (ii) Chang et al. [21] evaluated a virtual simulation application for nursing students, designed to improve knowledge and skills in medication administration and nasotracheal suction, demonstrating that using the mobile application reduced cognitive load and increased student satisfaction. (iii) Ataei et al. [22] developed a mobile application to perform common dosimetry calculations in radiotherapy, aimed at facilitating the work of oncology radiotherapy physicists and improving calculation accuracy.

In conclusion, medical simulation applications can leverage the unique features of mobile devices to enhance user experience and accessibility.

R4: Studies on the use of collaborative approaches in medical simulations were analyzed, such as: (i) Guinez-Molinos [23] developed the MOSAICO web platform for collaborative simulations in medical education. MOSAICO allows students to work as a team to design, execute, and evaluate clinical scenarios, reinforcing learning through the assignment of specific roles and peer and instructor feedback, improving understanding of teamwork workflows in clinical settings. (ii) Chua et al. [24] developed a 3D telesimulation tool for their Sepsis IPE program, where medical and nursing

students take on specific roles to practice early sepsis management. This program includes reflection modules and team feedback, facilitating the transfer of communication and collaboration skills to the real clinical environment. (iii) Kwon et al. [25] proposed using an educational program that incorporates game-based activities, such as role-playing games and collaborative challenges, to strengthen role understanding and communication skills in medical and nursing students. This program shows that collaborative games allow students to internalize teamwork and coordination in patient care.

In conclusion, it is recommended to integrate collaborative approaches in medical simulations, as they foster interpersonal and technical skills, facilitating preparation for interprofessional teamwork in the clinical setting.

In summary, the recommendations proposed for designing medical simulation applications include using gamification elements, such as reminders, levels, scoring, and rewards, to enhance engagement and learning in critical scenarios. Additionally, the problem-based learning (PBL) approach in virtual simulations can reinforce critical thinking and practical skills. Mobile applications stand out for their unique capabilities in user experience and accessibility, enabling accessible learning opportunities. Finally, the integration of collaborative approaches in simulations promotes interpersonal and technical skills, preparing students for interprofessional teamwork.

B. Recommendations for Designing a Medical Simulation Application Using AI

R5: The reviewed studies on LLM models such as GPT-4 focus on biomedical simulations and clinical communication skills practice. For example: (i) Zheng et al. [26] utilized a simulation-based teaching model, powered by ChatGPT 3.5, for cardiovascular disease education. This system provided immediate feedback and allowed students to conduct detailed clinical analyses in real time, significantly enhancing their clinical reasoning and practical skills compared to traditional methods. Students highlighted ChatGPT's ability to facilitate understanding of complex topics and its role as a support tool during simulations. (ii) Schaefer et al. [27] developed SimulateGPT, a biomedical simulator using GPT-4 to model complex biological processes through textual simulations, focusing on simulating living systems in immunology and oncology research scenarios. This model was qualitatively evaluated by experts, who praised its accuracy compared to GPT-4 without specific adjustments. (iii) Holderried et al. [28] investigated using a GPT-3.5-powered chatbot as a simulated patient for medical students to practice taking patient histories. The interface allowed students to interact with a virtual patient, providing a practice experience without the stress of direct supervision and with highly plausible responses in most cases. These studies show a positive acceptance in terms of usability and accuracy, highlighting the potential of LLMs to simulate patients and support the development of clinical communication skills in controlled educational environments.

In conclusion, using LLMs in biomedical and clinical simulations offers a valuable resource for learning practical and communication skills.

R6: Studies on using artificial intelligence to enhance communication skills in medical environments were analyzed. For example: (i) Hershberger et al. [29] developed ReadMI, a motivational interviewing training tool based on natural

language processing (NLP) that provides immediate feedback to trainees, improving their skills in asking open-ended questions and active listening. (ii) Liaw et al. [30] implemented a virtual reality (VR) simulation with an AI "doctor" agent in interprofessional communication training for nursing students. The artificial intelligence agent significantly improved students' self-efficacy in communication and their perception of its usefulness. (iii) Kobayashi et al. [31] used an AI-based video analysis tool to measure multimodal communication skills in physicians at a geriatric hospital. This AI training improved empathy and reduced burnout among participants.

In conclusion, the results suggest that using conversational AI to enhance communication skills in medical simulation applications can provide significant improvements.

R7: Studies emphasizing the use of AI models to supplement medical educational materials were reviewed. For instance: (i) Fazlollahi et al. [32] developed an AI-enhanced surgical curriculum at McGill University's Neurosurgery Simulation Center, where medical students received personalized feedback on technical competencies selected by AI. (ii) Naamati-Schneider et al. [33] explored the integration of ChatGPT as an educational tool in a healthcare management course, evaluating its impact on analytical skills development. ChatGPT's availability and efficiency in delivering key materials were highlighted by students as fundamental for improving their educational experience in healthcare. (iii) Thomae et al. [34] integrated ChatGPT into a medical course focusing on placebo and nocebo effects. Students valued the skills acquired in using AI to generate comprehensible and safe content for patients, as well as the ability to assess and improve AI-generated material for appropriateness.

In conclusion, these studies underscore the value of AI models like ChatGPT in the medical education context, supplementing educational materials throughout a medical course.

R8: Studies on using artificial intelligence in medical simulation applications with a focus on feedback for optimizing student skills were analyzed. For example: (i) Cold et al. [35] evaluated an AI system for beginners in bronchoscopy that provides automated feedback on identifying bronchial segments, helping students perform procedures with greater accuracy and efficiency. (ii) Kim et al. [36] developed a hybrid surgical simulator for endoscopic training, combining a physical model of the urinary tract with an AI interface that provides quantitative feedback on performance in renal stone detection, promoting advancements in students' endoscopic skills. (iii) Wang et al. [37] created the AIteach virtual learning system, which uses NLP to generate authentic clinical cases. The AI in AIteach provides detailed feedback on clinical reasoning and diagnostic decisions, thereby enhancing critical thinking and decision-making skills.

In conclusion, the use of AI-powered simulation systems with real-time feedback is recommended to enhance practical learning and clinical reasoning.

In summary, the recommendations proposed for designing a medical simulation application with artificial intelligence include optimizing LLM models tailored to the medical field to support clinical development, employing AI to enhance communication skills in medical settings, integrating AI

models to supplement educational materials such as curricula and courses, and using AI-powered feedback systems to optimize practical learning.

Table 1 summarizes the eight recommendations proposed for designing medical simulation mobile applications.

TABLE 1 Summary of Recommendations

Category	Recommendation	Details
Recommendations for the Design of a Medical Simulation Application	R1	Gamification elements: levels, score, rewards and goals [14] [15]
	R2	Implement PBL approach [17] [18] [19]
	R3	Leverage unique mobile devices features [20] [21]
	R4	Implement collaborative approach [23] [24] [25]
Recommendations for Designing a Medical Simulation Application Using AI	R5	LLM to enhance medical simulations [26] [27] [28]
	R6	Conversational AI to reinforce communication skills [29] [31]
	R7	AI to supplement educational material [32] [33] [34]
	R8	AI-generated feedback [35] [36] [37]

IV. ILLUSTRATIVE EXAMPLE

This section presents an illustrative example of five recommendations for designing a mobile medical simulation application, illustrating how these guidelines could potentially enhance medical education. The application comprises modules for simple simulation, group simulation, AI-driven virtual patient interactions, and AI-generated feedback. Each figure in this section highlights a distinct functionality, demonstrating how the integration of these recommendations can enrich learning experiences and improve clinical decision-making.

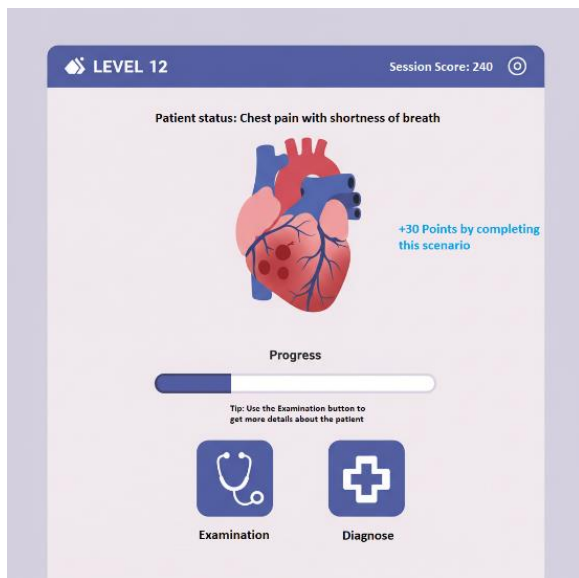


Fig. 1. Simple simulation scenario with gamification techniques.

Figure 1 shows the main interface for the simple simulation module. In this scenario, the user interacts with a clinical case featuring gamified elements such as a progress bar, level indicator, and session score. This design directly reflects recommendation R1, which advocates incorporating gamification strategies to enhance engagement and motivation in medical simulations.

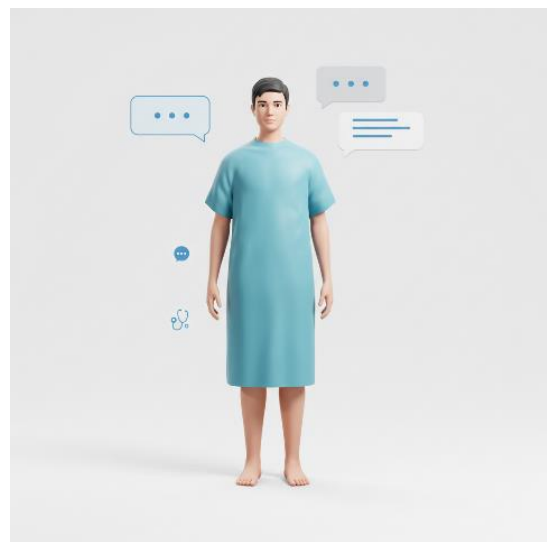


Fig. 3. AI virtual patient module

Figure 3 shows the AI virtual patient interface within the simulation application. It showcases a virtual patient, powered by AI, engaging in a simulated real-life diagnostic conversation, with their dialogue displayed in speech bubbles. This design aligns with recommendation R6, which emphasizes the use of AI to reinforce communication skills in medical simulations by providing realistic, interactive patient encounters.



Fig. 2. Group simulation scenario

Figure 2 shows the interface of the group triage simulation module. In this scenario, users engage in a dynamic clinical case that necessitates collaborative decision-making and critical analysis. The interface's design progressively reveals information and functionalities as the group advances. This approach aligns with recommendation R2, which emphasizes a Problem-Based Learning methodology, and recommendation R4, which advocates for a collaborative approach in medical simulations.



Fig. 4. AI generated feedback module

Figure 4 shows the interface for the AI-generated feedback module. In this view, the application analyzes data from the user's last three simulation scenarios and provides constructive feedback based on the user's session information. This design aligns with recommendation R8, which advocates for the integration of AI to deliver immediate and targeted insights, thereby fostering continuous improvement in clinical decision-making and simulation-based learning.

In summary, the illustrative example of the mobile medical simulation application integrates recommendations R1, R2, R4, R6, and R8 to enhance medical education. The figures demonstrate distinct functionalities: Figure 1 showcases a simple simulation interface with gamified elements (R1); Figure 2 presents a triage module that

facilitates collaborative problem-solving and a problem-based learning approach (R2 and R4); Figure 3 features an AI virtual patient designed to reinforce communication skills (R6); and Figure 4 displays an AI-generated feedback module that provides personalized insights based on the user's recent simulation scenarios (R8). Collectively, these figures offer a clear understanding of how these recommendations can be effectively implemented to enrich the learning experience and support clinical decision-making.

V. EARLY VALIDATION

This section describes an early initial validation performed to verify the applicability of the proposed recommendations. A mobile medical simulation application was used with recommendations R1 (Gamification), R2 (Problem-Based Learning), R3 (Mobile Features), R5 (LLM), and R8 (AI-Generated Feedback). The application includes three simulation modules for key medical procedures: cardiopulmonary resuscitation (CPR), wound suturing, and laparoscopic cholecystectomy. Each module offers a brief introduction and basic theoretical knowledge before users access the main "Simulation" menu. Upon access, a Large Language Model (LLM) trained with medical data dynamically generates a simulated clinical case.

The validation involved 18 final-year medical students from a university in Peru who interacted with the application designed with the proposed recommendations; the students are referred to as subjects. The researchers provided a brief demonstration and task assignments in each mobile application module. Subjects interacted with the mobile application throughout the case by selecting from a list of predefined alternatives. For each correct answer, the subject's score increased, and for incorrect answers, they received instant feedback explaining the correct solution.

When subjects finished solving the experimental cases, they completed a satisfaction survey (Satisfaction is defined as the contentment and positive attitudes towards the use of a product) [38]. The satisfaction survey was measured online using a 5-point Likert scale questionnaire based on the framework developed by Moody's [39], which defined a framework (based on the work of Lindland et al. [40]) to evaluate satisfaction in terms of Perceived Ease to Use (PEOU), Perceived Usefulness (PU), and Intention to Use (ITU). This framework has been previously validated and is widely used. The possible answers for each statement in the PEOU, PU, and ITU questionnaire are: Totally disagree, Fairly disagree, Neutral, Fairly agree, and Totally agree. A numerical value is provided to each statement from 1 (Totally disagree) to 5 (Totally agree). Six questions were defined to measure PEOU, the metric was calculated adding the numerical values of the answers and classifying into a rank of five possible values: Rank 1–6: Totally disagree, Rank 7–12: Fairly disagree, Rank 13–18: Neutral, Rank 19–24: Fairly agree, Rank 25–30: Totally agree. For example, if a subject answers 5 questions with Totally agree and 1 questions with Neutral in PU, the result of this metric will be 28 (Totally agree). Six questions were defined to measure PU; the metric was calculated adding the numerical values of the answers that each subject filled in through the eight questions, the result of this addition is classified into a rank with the five possible options: Rank 1–8: Totally disagree, Rank 9–16: Fairly disagree, Rank 17–24: Neutral, Rank 25–32: Fairly agree, Rank 33–40: Totally agree. Six questions were defined to measure ITU, the metric was calculated adding numerical

values of the answers and classifying the result into a rank of two possible values: Rank 1–2: Totally disagree, Rank 3–4: Fairly disagree, Rank 5–6: Neutral, Rank 7–8: Fairly agree, Rank 9–10: Totally agree. Figure 5 shows the satisfaction results.

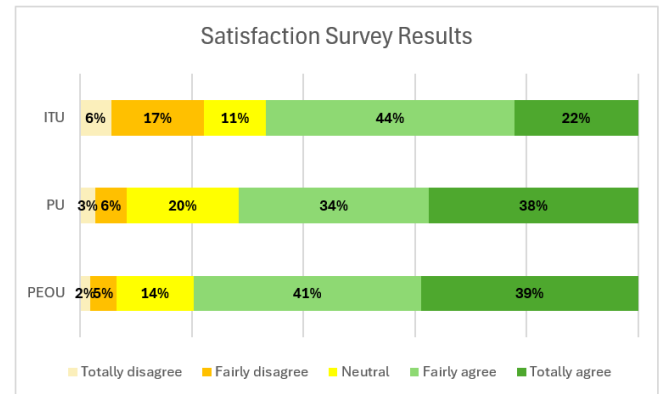


Fig. 5. Satisfaction survey results

Figure 5 shows a divergent stacked bar of the responses provided by subjects to the questionnaire for this property: For Perceived Ease of Use (PEOU), approximately 39% totally agreed and 41% fairly agreed (over 80% total), suggesting that the majority of subjects considered the application mobile to be easy and potentially useful to use. For Perceived Usefulness (PU), approximately 38% totally agreed and 34% fairly agreed (over 72% total), suggesting that the majority of subjects considered the application mobile to be useful. For Intention to Use (ITU), approximately 22% totally agreed and 44% fairly agreed (over 66% total), suggesting that the majority of subjects intend to use the medical simulations mobile app. A minority of subjects are undecided and do not perceive the application as useful.

VI. CONCLUSIONS

This work summarizes a set of eight recommendations for designing a mobile application for medical simulation. A total of 24 research studies on medical simulations were analyzed. Recommendation R1 suggests using gamification elements, R2 advocates for a PBL approach in medical simulations, R3 proposes designing medical simulations on mobile applications, R4 recommends a collaborative approach, R5 emphasizes the use of LLM models tailored to the medical field, R6 suggests using AI models to reinforce communication skills, R7 recommends using AI models to supplement educational materials such as curricula and medical courses, and R8 suggests integrating AI models to provide feedback to users within the application.

This work provides an illustrative example of a mobile medical simulation application design that integrates recommendations R1, R2, R4, R6, and R8. This example demonstrates how these recommendations can be leveraged to boost medical education through simulations. Furthermore, a preliminary validation study was conducted with 18 subjects medical students, providing initial evidence of the feasibility and user acceptance of the proposed recommendations. The results of this early validation indicate a high user perception of usefulness and ease of use, suggesting that applications designed with these recommendations can be effective and well-received tools for medical education. Therefore, future work will focus on rigorously validating the recommendations

through large-scale empirical experiments and expanding the theoretical framework.

Future work considerations include: (i) Reviewing more related studies to extract additional recommendations for designing mobile applications for medical simulation, (ii) Conducting empirical experiments with subjects to assess the effort, perceived usability and satisfaction of using mobile medical simulation applications based on the proposed design guidelines, (iii) Conducting empirical experiments with medical simulation designers using the proposed recommendations to assess their applicability and usability, and (iv) Identifying and incorporating various approaches to the design of mobile medical simulation applications such as adaptive learning systems, gamification strategies, and context-aware functionalities.

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