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Clinical Simulation in Complexity: Simulation-Based Learning for Medical Training

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Abstract

The social isolation and distancing measures which followed the COVID-19 pandemic promoted clinical telesimulation and virtual simulation as a didactic strategy for training medical students. These strategies have not yet been fully evaluated in terms of impact and acceptability. This study evaluates virtual simulation and telesimulation strategies applied during the pandemic from the perspective of students, professors, and experts in clinical simulation. A qualitative method was applied to 56 medical students studying semiology and 12 professors. The students and professors conducted clinical simulations during in-person classes assisted by information and communication technology (ICT). Follow-up was conducted for 18 months. The intervention focused on tele-simulation and in-person ICT-assisted classes. The measurements focused on students' perceptions of the practice and of professors relating to developing skills and competence. During remote debriefing, students gave simulations an average rating of 6.43/7. Measuring the competence development (generic and specific) showed a rate of 82.2% at different times during the simulation, corresponding to the 80% level of development given by professors' evaluations in real scenarios. Using a simulation-based didactic strategy in the form of ICT-assisted in-person classes prior to the practical training stage required for medical students was pertinent, efficient, and found to be favourable during the pandemic. Including this innovative strategy in the curriculum, even after returning to in-person classes, is recommended because it offers academic support in training doctors and developing high-level competencies.

Keywords: Medical simulation, Tele-simulation, Pandemic, Simulation-based learning, Educational innovation, Complexity.

Introduction

The global public health situation triggered by the COVID-19 pandemic led to the implementation of isolation and social distancing measures during the year 2020, which increased the use of the simulation-based learning strategy (SBL) in the modality of telesimulation and virtual simulation assisted by information and communication technologies (ICT) ¹. During the pandemic, training activities were abruptly suspended, which was a worrisome situation for many educators ² and for the students, who had limited contact with patients and the development of their clinical skills ³. Therefore, educators had to innovate, using different didactic strategies assisted by ICT, to allow the incorporation of virtuality, which complements SBL for academic transformation and the construction of safe environments for

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immersion in simulated hospital settings⁴⁻⁶. Therefore, a virtual SBL must integrate knowledge and training achieved during in-person sessions^{7,8}. As such, higher education institutions have organised their academic activities to incorporate virtual, in-person processes assisted by ICT and SBL (preferably based on real clinical cases).

For both undergraduate and medical-surgical specialty training programs, the COVID-19 pandemic generated different impacts, such as decrease in clinical and research practical academic activities, changes in the assignments and tasks of personnel in training, adaptation to biosecurity measures, changes in patient care modalities (telemedicine), development of competencies for the use of virtual tools and innovation of didactic strategies (SBL and other synchronous or asynchronous remote techniques)⁹. Integrating innovative strategies to promote health education has been a recurring practice during the COVID-19 pandemic¹⁰. The SBL strategy has been used to standardise the evaluation process (headings and objective structured clinical examinations), which allows for measuring SBL's effects on the development of the generic and disciplinary competencies of medical students^{11,12}. One of the basic requirements in implementing an educational model involving immersion in simulated environments is the adequacy of the simulated environments in terms of high technological fidelity equivalent to real clinical scenarios, called 'services'¹³⁻¹⁵. Innovative educational scenarios are important, given the isolation and confinement measures to mitigate the spread of COVID-19¹⁶. These considerations highlight the need to implement innovative models of medical education based on simulations.

The frequency of including SBL for curriculum transformation in under- and postgraduate medical education is increasing. SBL allows for the iteration of training in controlled environments that represent clinical scenarios and facilitates feedback during practice¹⁷⁻¹⁹. For example, Yale University uses modules that integrate basic and transversal components²⁰ to complement academic training and clinical decision-making processes²¹ to improve students' problem-solving, critical thinking, systemic-complex thinking, cooperative work, and communication skills^{22,23}. Studies conducted on telesimulation have found an important need to evaluate its impact given their constant evolution resulting from technological advances and published experiences²⁴. Therefore, our objective is to evaluate telesimulation and virtual simulation, not only from the perspective of students but also the teachers involved with the simulation in the institution, teachers in the institution of practice and simulation experts at simulation centres, as well as its impact on the generic and specific competencies of the students.

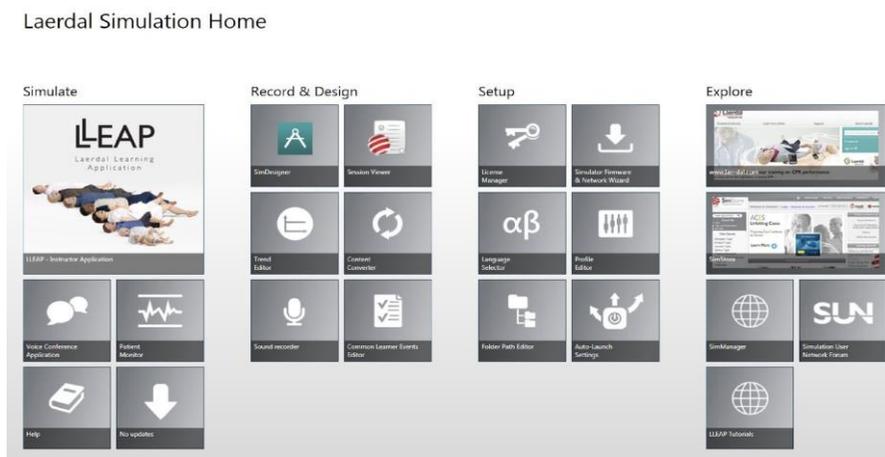
Methodology

This qualitative study implemented SBL strategies through distance learning (tele-simulation) and ICT-assisted in-person classes as part of the undergraduate medical program of a higher education institution in southern Colombia. The School of Medicine of the institution has an agreement with the two main hospitals of the city, institutions of high level of complexity where students perform their training practices. Students who are taking the Semiology course perform an average of 240 hours of clinical practice and, as they advance in their career, during the following two semesters, an average of 480 hours of clinical practice corresponding to the Internal Medicine course. All students perform clinical simulation activities in an average of 50 hours and then rotate through the different hospital services in groups of 5 or maximum 6.

However, with the onset of the COVID-19 pandemic, students were unable to continue attending healthcare institutions. Given the immediate need to transition to online learning, simulation

activities became the contingency plan for students enrolled in all clinical courses. In order to evaluate the impact of the emergency plan on the quality of academic training, it was decided to carry out the present research project with students who were taking the semiology semester. This population was selected because semiology is the first subject with hospital internships and therefore there would be no bias at the time of measuring practical performance. With the beginning of the confinement, during two weeks of preparation, a schedule of telesimulation practices was designed to train the students. Fifty-six students were enrolled in the semiology course who began to develop the distance simulation activities designed by the family medicine specialists who lead the course.

Initially, 100% virtual and distance activities were carried out, consisting of confronting the students with clinical cases through Laerdal's LLEAP® platform (Figure 1), licensed to the educational institution. The students communicated through the Teams® meeting platform with the teacher in order to solve the challenge posed, i.e., the clinical case identified by the specialists on the platform that resembles the situations observed in health institutions, is presented to the students and they are asked to develop the process of approaching the clinical situation to take an adequate clinical history and to define the signs and symptoms that should be taken into account when examining the patient, which can be simulated through the LLEAP® platform, which already has scientific evidence of its usefulness for this purpose ²⁵.



^aLink: <https://laerdal.com/la/>

Figure 1. Launch page of the LLEAP platform. ^a

As the contingency measures became more flexible and it was possible to authorize the entry of students, with all the biosafety measures, to the simulation clinic scenarios, the activities began to be carried out in a mixed manner. From each rotation group, only one student attended, different for each session, while the others connected from their homes through the Teams® platform and the professor or instructor of the simulation clinic developed the corresponding case with the active participation of both the student who was in the scenario and those who were remotely. This strategy was progressively extended, increasing the number of students attending the simulation clinic at the same time as the students performed the exercises in the virtual modality. Both virtual and blended sessions had a duration of 120 minutes, including debriefing

time, which were alternated with the classes that were usually scheduled (also virtually) for the course. The 2020-I semester ended, and the conditions remained similar. For the next semester, the students could begin to return to the health institutions, in reduced numbers, so that the telesimulation practices, virtual simulation and remote classes continued to be carried out, now with the focus of the internal medicine course that adds the part of the diagnosis and comprehensive management of the patient.

To promote the participation of remote students, the "chat" function was enabled in the Teams® platform and students were encouraged to ask questions, make observations and provide their own approach to the simulated situation. Subsequently, given the persistence of the contingency measures and the adequate reception of the students to the activities proposed, it was decided to continue with the didactic strategies of simulation, virtual simulation and telesimulation as part of the regular training process during the year 2021 with the additional purpose of covering the second semester of the subject of internal medicine.

The fundamental objective of telesimulation activities is to enhance students' generic competencies. Although technological advances are being applied with increasing force in the field of medical training and professional practice, the pandemic generated an additional need to generate the development of these competencies. For this reason, the simulation sessions at the beginning of the pandemic (exclusive remote modality) were directed in terms of competencies to the cognitive aspect and complex thinking with the use of these digital tools. When the students began to return to the simulation environments, the simulation activities began to focus mainly on improving communication skills and teamwork with an interdisciplinary approach.

During the third semester of observation, students were already able to attend clinical practice hours normally, with strict biosafety measures. It was then decided that, in addition to these hours, they should perform the equivalent of 30% of hours in simulation scenarios, i.e. 72 hours during the semester, which were now performed with a comprehensive approach, incorporating digital tools with the development of generic competencies and interdisciplinary work for the approach and solution of clinical challenges, challenge-based learning. In order to provide continuity throughout the course and during all activities, it was decided that students would perform simulation practice on cases whose main topics had already been reviewed in class. Likewise, all topics are reviewed based on the clinical practice guidelines used in health institutions. The evaluation of the semiology course was based on the performance achieved during the virtual class sessions, the telesimulation activities and the regular exams. For the first semester of the internal medicine course, in which they could already perform face-to-face activities, the objective structured clinical examination (OSCE) evaluation method was used to quantify the development of simulation and professional competencies, validated by authors such as Fonteneau²⁶. For the last follow-up semester, the professional competencies evaluation rubric was also used both in the evaluative activities of the OSCE session and in the formative practice scenario, and perception questionnaires were sent to students, professors and external experts.

Finally, standard perception survey forms with a Likert-type scale (1= totally disagree to 5= totally agree) were sent to the students, as well as to the instructors of the simulation scenarios and to the teachers who accompany the training practices. The evaluations of perception of the activities were anonymous and the students sent them before receiving their final grade. In the case of Colombian and international referents, an open interview on the impact of simulations during the COVID-19 pandemic was conducted at the following institutions:

- Arizona Simulation Technology and Education Centre (ASTECC), University of Arizona (USA).
- Shelden Clinical Simulation Centre, University of Missouri (USA)
- Centre for Teaching and Certification of Medical Skills (Simulation).
- Universidad Nacional Autónoma de Mexico (UNAM).
- Centro de Simulation Clínica del Tecnológico de Mexico City (Mexico).
- Centro de Simulation Clínica del Tecnológico de Monterrey (Mexico).
- Centro de Simulado de la Universidad Mariana (Pasto, Colombia).
- Hospital Simulado de la Universidad de la Sabana (Chía, Colombia).

Data Analysis

The participants completed the online surveys on a digital form that was automatically collected in a database and later downloaded to Excel. Thus, the data were processed and descriptively analysed after obtaining the participants' approval. Furthermore, the categories of all qualitative variables of the applied instruments and interviews were recorded.

Ethical Considerations

This study complied with the ethical principles. This study obtained consent from the participants during the beginning of the COVID-19 pandemic. The simulation protocols were verified and approved by the institution. Therefore, those participating in SBL were not exposed to any harm.

Results

The students were evaluated in relation to their competencies in the simulation scenario with the rubric applied during the OSCE, which allowed establishing the development of generic competencies observed mainly during the simulation process and the specific ones observed during the clinical simulation and during the formative practice. All students passed the evaluation, with a mean score of 4.11 (SD 0.37) for the generic competencies (Figure 2), while they obtained a mean score of 4.0 (SD 0.43) in the evaluation of the practical competencies (Figure 3). These scores were similar to those obtained by students in the subjects evaluated during the 5 semesters prior to the onset of the pandemic (there were no statistically significant differences when applying the Student's t-test for difference of means).

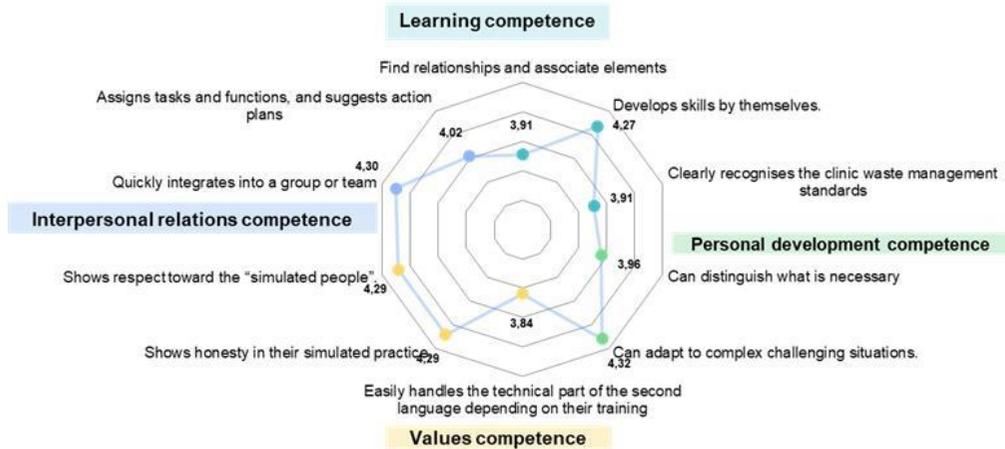


Figure 2. Students' assessment of their generic competencies.

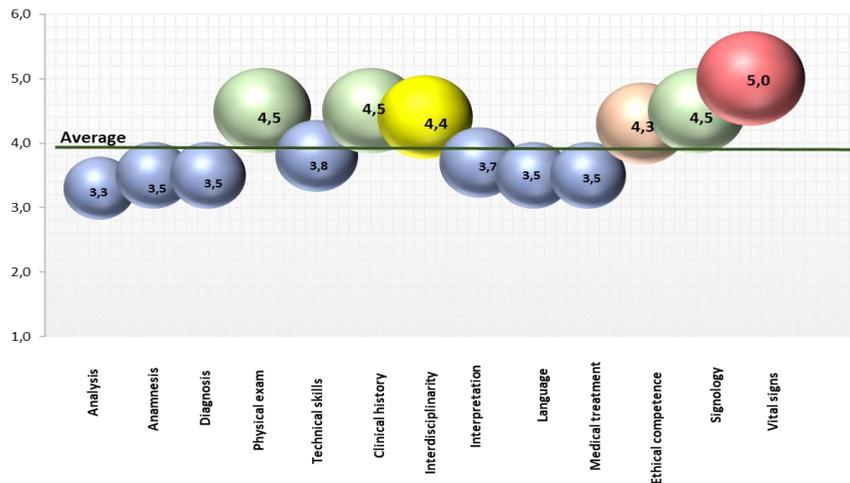


Figure 3. Clinical competence ratings given by the professors at the healthcare institution.

All fifty-six students completed the course evaluation survey (Figure 4). No student rated the experience lower than 3.5, 78% of the responding students rated the course as excellent (grade higher than 4.5), while 11% rated it as good (grade higher than 4.0). Students found the activity useful for validating knowledge construction, developing cooperative learning exercises and performing more complex processes of analysis and argumentation. It was also important for the students that the process carried out, starting in virtuality and culminating in the combination of simulation activities with clinical practices, allowed them to acquire the necessary skills for

patient care.

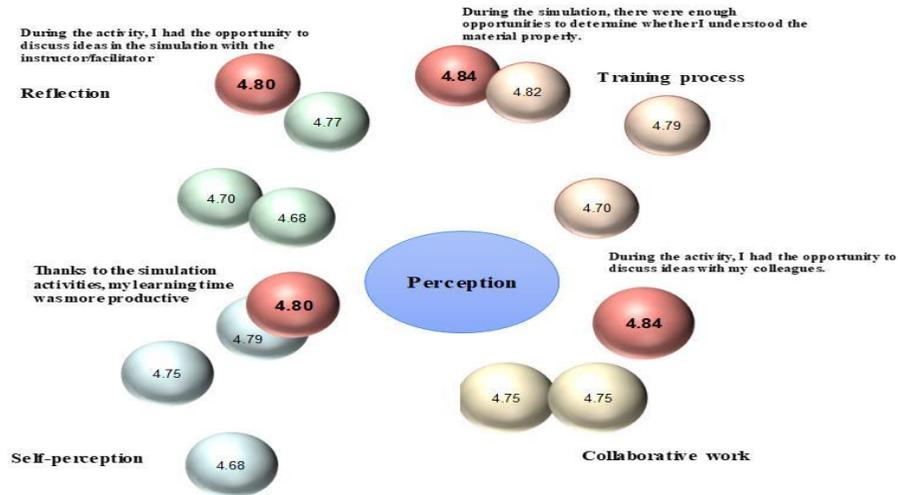


Figure 4. Students' perceptions of the simulation activities.

The quality of teaching in the course was rated as excellent or good by 98% of the students who responded. 95% of the students considered that the content of the contingency period with full virtuality allowed them to master the basic knowledge related to the topics of the programmatic content, and that later with the mixed activities and the return to face-to-face attendance at the health institutions they were able to integrate the knowledge because they had a good level of recall (metacognition/meaningful learning). The students mentioned that the Debriefing sessions were what mainly helped them to consolidate their knowledge. During the sessions, the students and the instructor highlight the positive actions observed during the simulation activity and emphasize the way in which one can learn from the incorrect actions performed during the simulation. Figure 5 shows the main aspects that students highlight from the processes performed during the debriefing:

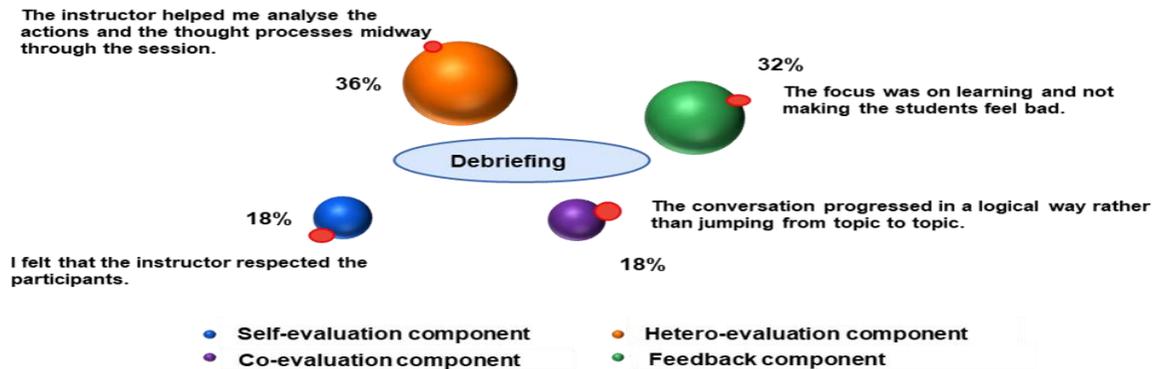


Figure 5. Students' perceptions of activities during debriefing

Outside Expert Interviews

Table 1 summarises the perceptions of national and international experts, instructors, and institutional professors. The categories were established to describe and analyse the outside experts' perceptions (total of 11 interviewees), the professors and instructors participating in the study (11 interviewees), and the professors and instructors who took part in the study (12 interviewees).

Perceptions and opinions of simulated activities during the COVID-19 pandemic			
Interview topic		Outside experts	Professors and instructors participating in the study
Simulation strategies and experiences during the new conditions established by the pandemic		<ul style="list-style-type: none"> -Synchronous and asynchronous virtual simulation execution. -Biosecurity protocol strengthening for managing patients with COVID-19. -Hybrid tele-simulation -Not all the students had become familiar with the simulation strategies. -The suitability of the instructors in the simulation activities must be guaranteed. 	<ul style="list-style-type: none"> -Synchronous and asynchronous virtual simulation execution. -Developing ICT – assisted face-to-face activities that comply with biosecurity and distancing protocols. -Not all students had become familiar with the simulation strategies. -All the professors and instructors in the university programs need to be encouraged to participate in simulation training.
Tele-simulation benefits		<ul style="list-style-type: none"> -Retraining of professionals who are in rural areas. -Development of the competences associated with the use of communication technologies. -Innovation of pedagogical strategies. -Development of critical thinking for decision-making. -Schedule flexibility and increased accessibility. -Cost decreases and continuing education. -Preservation/protection of simulation equipment. 	<ul style="list-style-type: none"> -Development of the competencies associated with the use of communication technologies. -Innovation of pedagogical strategies. -Schedule flexibility and increased accessibility.
Scope and limitations of the interdisciplinary simulation activities	Scope	<ul style="list-style-type: none"> -Professional improvement. -Comprehensive competence development. -Iteration of activities to improve skills. -Safe scenarios for the participants. 	<ul style="list-style-type: none"> -Professional improvement. -Comprehensive competence development. -Safe scenarios for the participants.

Perceptions and opinions of simulated activities during the COVID-19 pandemic			
Interview topic		Outside experts	Professors and instructors participating in the study
	Limitations	<ul style="list-style-type: none"> -Difficulty in organising schedules between the participants of different programs. -Lack of fidelity in scenarios for some participants compared for others. 	<ul style="list-style-type: none"> -Difficulty in organising the schedules between the participants of different programs. -Apathy when facing an error as a result of recognising that it is in a simulated environment. -Technological loyalty is diminished in the cases when the subject of the practice makes recreation difficult in the simulator.
Addressing continuous improvement of ABS		<ul style="list-style-type: none"> -Ensure professors undergo training to become simulation experts. -Increase cross simulation. -Enhance student satisfaction with the activities. -Search for the development and/or application of technologies applied to simulations. 	<ul style="list-style-type: none"> -Finding student satisfaction with the activities. -Search for the development and/or application of the technologies applied to the simulation.
Emerging technologies		<ul style="list-style-type: none"> -These technologies increase the immersion of the students into the scenarios. -Comprehensive skill development. -Costs can be reduced and accessibility improved. 	<ul style="list-style-type: none"> -These technologies increase the immersion of the students into the scenarios. -They motivate students to participate in simulated exercises.
Achievements of simulation activities		<ul style="list-style-type: none"> -Cases that in a real scenario would not be available for a student can be simulated to develop their skills. -Indicators of patient safety in health institutions are improved. 	<ul style="list-style-type: none"> -Universities can carry out total immersion through the simulation activities. -Trust is generated in the student (self-perceived and that perceived by the professors) for the development of the different healthcare procedures.
Advantages of including clinical simulations in curricula		<ul style="list-style-type: none"> -Guarantee the development of clinical skills promotion activities. -Promote meaningful learning and learning for life. -Practices are standardised. -Achieve better and more objective evaluation processes. 	<ul style="list-style-type: none"> -The theoretical review modality followed by simulation and then clinical practice improves the construction of knowledge. -Students improve their BEING competencies, mainly from

Perceptions and opinions of simulated activities during the COVID-19 pandemic		
Interview topic	Outside experts	Professors and instructors participating in the study
	-Increase students' self-confidence level.	strengthening their communication competencies.

Table 1. Experts', professors', and instructors' perceptions of simulations

The experts consulted clinical simulation as a successful tool in the medical training process, aimed primarily at improving the skills, abilities, and competencies necessary for students to perform optimally in the healthcare scenario. The ICT applied to the simulation had advantages in terms of accessibility, the variety of didactic strategies, the motivation it generated in the students, and the possibility of solving clinical challenges, all of which aimed to promote complex thinking and meaningful learning.

Discussion

At the onset of the COVID-19 pandemic, health faculties had to take action to ensure the quality training of medical students by guaranteeing safety and avoiding the situation of not being allowed to enter health institutions²⁷. The public health situation and the conditions for teaching led health faculties to face an unprecedented challenge; student participation in patient care was suspended. Students were left at home moving through their academic schedule but not knowing how they could continue their practical training during the pandemic.

Faculties had to act quickly and creatively to provide students with activities that, while virtual, were of high quality and ensured that learning objectives and outcomes were met. Given that the effectiveness of virtual education for medical students has already been studied and determined^{28,29}. Due to the unique nature of healthcare programs, program educators had to undertake new strategies using a combination of technological resources. The traditional semiology core course was successfully modified to be developed online in a two-week time period. The online classroom and simulation methodology allowed for student participation, feedback and assessment for student learning.

Many students were able to complete the semiology course exclusively through an online platform. For the most part, the learning objectives, competency development and adequate formative level for the next subject, internal medicine, were met. Most students rated the course overall as excellent. The blended course of the internal medicine course is consistent with the andragogical theory of "blended learning" that maximizes educational benefits³⁰. The function of the Teams® platform with its possibility for interaction with the teacher via chat was also well received and created a learning environment conducive to improving student engagement during the virtual simulation activities and later in the blended and finally in the return to the formative practices.

The cases that were used for the simulation activities were obtained from the practice scenarios, some of them completely related to the pandemic situation, so that students could be offered interactive problem-solving activities, challenges, and observation of different levels of feedback which is useful to improve learning outcomes, motivation and attitudes of students³¹. This self-structuring and constructivist learning methodology provides students with the opportunity to work independently, develop critical thinking and relate knowledge to skills³².

Numerous reports in the literature supported participants' perceptions of SBL and its impact on developing competencies that improve student trust³³⁻³⁵. The present study goes a step further by showing not only that students consider virtual medical education to be a good option in terms of motivation and development of soft skills and competencies for clinical simulation and debriefing, but also shows that there is a possible correlation between such development and the acquisition of specific competencies for performance in clinical practice scenarios. The conditions under which the simulation was carried out: interactive review of the subjects (virtual and then face-to-face), followed by simulation activities with feedback for learning from the perspectives of self-evaluation, co-evaluation and heteroevaluation, to end with practical rotations in health institutions; are conditions that should be replicated in different undergraduate subjects and even in postgraduate training to validate the transfer of competencies for virtual and face-to-face simulation to clinical scenarios.

Self-evaluation is an integral part of the teaching and learning processes in higher education, as it allows highlighting students' positive and negative actions without any judgement from professors or other participants. Students evaluated debriefing as a satisfactory self-evaluation process for simulated training. As shown in Figure 3, the students highlighted that conducting the debriefing process without any judgement while respecting other participants was essential. Previous studies supported this study's findings in those positive reinforcements, pointing out the aspects to be improved, and identifying the knowledge gaps generated during the debriefing process produced greater motivation and training to improve clinical practice³⁶⁻³⁹. The self-evaluation process complemented the students' good performance in their practical training stage and developed their clinical competencies.

Medical students who conducted simulated training prior to the practical training stage developed generic competencies more easily than those who had not experienced this strategy. Figure 4 highlights the positive impact of teamwork competencies on developing values related to the students' ability to adapt to complex challenges. These findings are consistent with those reported by Fajardo Dolci¹⁴ who concludes that this competence is optimally developed in simulation environments, which in turn can be related to improved patient safety indicators and the increased use of ICT. By contrast, this was not shown in our research because we focused on establishing a close relationship between teamwork and competence development, as suggested by various authors⁴⁰⁻⁴². The greatest benefit of simulation environments is that they provide students with holistic competence.

Interdisciplinarity is part of the training process and improves technical skills, complex thinking abilities, and the ability to develop an ideal work profile to meet the challenges of professional practice. Figure 5 shows that simulations are better in terms of allowing students to practice their technical skills and interdisciplinary competencies, along with ethics in the training scenarios. These findings coincide with those of Espinosa-Ramírez et al.⁴³ and Peng et al.⁴¹, who referred to teamwork as the main benefit for students in health programs. Adjusting to the systemic thinking process during simulated training to better integrate and analyse clinical and paraclinical information is considered relevant. Clinical simulations can be integrated into curricula to advance medical student training using educational technological tools. This strategy can improve the achieved performance before starting practical training.

Table 1 highlights how opinions have converged towards the fact that the greatest benefit of simulations is their usefulness in competence development by highlighting the advantages of

applying the theory-simulation-practice strategy as an academic reinforcement in the training process. The opinions of the professors and instructors agreed with the findings of Alkhateeb et al.¹¹ and Grenno Troitiño et al.¹² regarding the advantages provided by simulation scenarios for evaluating medical students in training. Furthermore, the findings were supported by different studies, which reported that successful simulations manifested in loyalty to participants' roles in a credible environment for developing simulated cases, which allowed the development of clinical reasoning, where conceptual, physical, environmental, and emotional fidelity converged⁴⁴⁻⁴⁵.

Conclusion

This study evaluated the results of incorporating an SBL didactic strategy into medical training and its perception during the COVID-19 pandemic. The consensus was that SBL exhibited satisfactory results in developing competencies with adequate student adherence, which positively affected professors' perceptions during students' practical training stages in health institutions.

Design strategies in medical education training that integrated SBL, systematised to occur after theoretical learning and prior to clinical practice, supported by a curriculum transformation in the undergraduate medical curriculum, allowed for improvements in students' skills, abilities, and competencies throughout the practical training stage.

Therefore, the objective processes to evaluate students enrolled in medical-surgical courses provided continuity in implementing the SBL didactic strategy for students in medical specialties and subspecialties. This approach addressed interdisciplinarity, complex thoughts, and emerging technologies that facilitated the development of systemic, scientific, critical, and innovative ideas.

Since this study was not conducted with a randomly selected sample and did not have a control group, it is not possible to guarantee that the improvements found in the students are entirely due to the intervention or that the results are comparable or even better than those of usual simulations. However, as the evidence suggests that the distance modality increases the technical skills of medical students, we recommend continued research to confirm our findings and monitor the evolution of emerging technologies applied to clinical simulation.

Data Availability Statement

Research data are not shared.

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