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Influence of the use of new technologies in medical semiology education. Systematic review.

Influencia del uso de nuevas tecnologías en la educación de semiología médica. Revisión sistemática.

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Summary:

Introduction: The digital age has transformed the educational field, offering tools that enrich both learning and teaching. In medical semiology, emerging technologies, such as detailed simulations and interactive visualizations, have facilitated the teaching of medical conditions and enabled virtual clinical practices, which are essential for the training of medical students.
Objective: To explore the influence of emerging technologies on the teaching of medical semiology in medical schools globally.
Materials and Method: A systematic review of the literature was conducted following the PRISMA-SCR protocol, with a search in the Web of Science and SCOPUS databases. Peer-reviewed articles published between 2020 and 2024, in Spanish and English, were included. The selected studies were evaluated according to inclusion and exclusion criteria.
Results: Thirteen articles were reviewed and organized into three categories: i) Improvement in Academic Performance and Clinical Skills, ii) Student Satisfaction, Motivation and Engagement, and iii) Impact on Learning Continuity and Flexibility. The categories of "Improvement in Academic Performance and Clinical Skills" and "Impact on Learning Continuity and Flexibility" turned out to be the most relevant. The findings indicate a significant improvement in the acquisition of theoretical knowledge and practical skills, as well as a positive perception of students about the pedagogical utility and realism of technological tools. **Conclusion:** The use of emerging technologies has a positive impact on the teaching-learning process of medical semiology. These tools improve both academic performance and the development of clinical skills, in addition to providing flexibility and accessibility in learning.

Keywords: Technologies; Teaching; Semiotics; Semiology; Medical Students

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Conclusion: The use of emerging technologies has a positive impact on the teaching and learning process in medical semiology. These tools enhance academic performance and the development of clinical skills, while also providing greater flexibility and accessibility in learning.

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1. Introduction

Medical semiology, a fundamental pillar of clinical diagnosis, addresses the meticulous study of the signs and symptoms that characterize human pathologies. This discipline is indispensable to achieve accurate diagnoses and to facilitate effective communication between health professionals through the use of standardized terms (1). Traditionally, the teaching of semiology has depended on methods centered on the patient and the manifestations of diseases (2), which are candidates to expand significantly through the integration of advanced technologies, understanding all technology as "a set of theories and techniques that allow the practical use of scientific knowledge" (3), also emphasizing its fundamental etymological characteristic coming from the Greek *téchnē* + *logos* , that is, any element that allows the study of a trade, skill or art, such as medicine.

The digital age has influenced the educational landscape, offering tools that enrich both learning and teaching. These technologies enhance the teaching of semiology by providing detailed simulations and interactive visualizations of medical conditions, and by enabling virtual clinical practices that are fundamental to health sciences education (4). Technological resources, including simulation software, online learning platforms, interactive databases, and high-fidelity simulators, expand learning opportunities and influence skill development by making more clinical cases accessible, homogenizing practical experiences among students, and improving continuing medical training in diverse contexts (5). Medical education must evolve to prepare future physicians for digitalized and globalized healthcare contexts (6).

This systematic review aims to explore the influence of emerging technologies on the teaching of semiology within medical schools. The study details the technologies applied, describes their integration into curricula, and assesses their impact on the development of students' clinical skills. This analysis also considers how these technological tools support a biopsychosocial approach, demonstrating that medical education has been transformed over time in search of meeting the needs of each era (7).

Adhering to the PRISMA-SCR protocol guidelines (8) and under the supervision of medical education expert Álvaro Andrés Herrera Alcaíno, gynecologist surgeon, graduate of the University of Chile, national director of Medical Education at the Universidad San Sebastián and the University of Chile and Coordinator of the Continuous Education Improvement Unit of the School of Medicine, this review ensures a rigorous and transparent approach in the evaluation of the existing literature, answering the results reported in the literature when using various technologies for teaching medical semiology to undergraduate students.

2. Methods

Review protocol

The systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-SCR) protocol.

Search strategy

A systematic review based on a Scoping Review protocol was conducted, searching two databases, Web of Science (WOS) and Scopus, applying filters to select peer-reviewed articles published between 2020-2024, in Spanish and English. In addition, a controlled vocabulary was used based on keywords obtained from MESH Terms and ERIC Thesaurus. The search was carried out in these two databases due to their academic recognition, which allows us to guarantee that the search results cover exhaustive and high-quality coverage. On the other hand, Web of Science and Scopus are easily accessible platforms, containing literature validated by a rigorous selection process, with high impact and guaranteed quality.

Table 1. Identification and expansion of the basic search concepts.

Search for articles with an emphasis on "semiological education in medical students" (words combined with OR and AND)
WOS: medical education, clinical teaching, medical students, semiology, clinical signs, semiology, semiotics.
SCOPUS: medical education, education technology, medical students, semiology.

Table 2. Search strategies used.

Base de datos	Date	Search strategy	Results
WOS	May 13, 2024, 5:20 p.m.	Article Abstract: ("Medical Education" OR "Clinical Teaching") AND ("Medical Students") AND ("Semiology" OR "Clinical Signs" OR "Semiology" OR "Semiotics") MUST INCLUDE semiology MUST INCLUDE education. Publication date: last 5 years	32
SCOPUS	May 13, 2024, 7:00 p.m.	Article title, Abstract, Keywords: (Medical AND education) OR (education AND technology) OR (Medical AND students) AND (semiology). LIMITED TO medicine LIMITED TO article. Publication date: last 5 years	26

Relevance screening and inclusion criteria

A controlled vocabulary based on keywords rectified in MESH Terms and ERIC Thesaurus was used, resulting in a total of 58 articles. These were analyzed by creating an Excel spreadsheet to select based on inclusion criteria (original, qualitative, quantitative, mixed articles) and exclusion criteria (articles not focused on medical student education, reviews, comments and editorials).

Selection process

Once non-contingent articles were eliminated, the number of articles was divided equally so that all authors independently reviewed the titles and abstracts of each selected article, verifying that each one met the inclusion criteria, excluding those that met the exclusion criteria, and eliminating duplicates. After this, the articles were read in full.

Data collection

All authors read the articles and extracted relevant information from each one, previously selected based on a team discussion, including the title of the article, the year and authors, the design of the studies, the number of participants, the instrument used for data collection and the main findings, maintaining relevance in the influence of the use of technologies for teaching medical semiology.

Classification of experiences

The experiences were then classified into three emerging categories: 1) Improvement in Academic Performance and Clinical Skills; 2) Student Satisfaction, Motivation and Engagement; and 3) Impact on Learning Continuity and Flexibility.

Bias assessment

Two authors performed the risk assessment in a careful and systematic manner based on the ROBINS-I and NIH tools to assess the risk of bias in the reviewed studies, using the official parameters present on the respective websites (Cochrane Methods and NIH.gov).

3. Results

Selection of studies

The systematic review identified a total of 58 articles. Of these, 10 articles were excluded as duplicates. Of the remaining articles, 48 were selected based on their title and abstract. A full-text review was performed on the selected articles. Of the studies, 35 did not meet the inclusion criteria and 13 final articles were designated as meeting the inclusion criteria.

Characteristics of the studies

The selected studies were published between 2020 and 2024, mainly since 2022, reflecting the interest in current medical education research on the verge of implementing various cutting-edge technologies. Likewise, the impact of the COVID-19 pandemic is evident as a driving force for the implementation of technologies in the teaching of medical semiology. This is made explicit in the theoretical framework of the selected studies. The great continental diversity of countries that conducted the selected articles stands out, addressing countries in America, Europe and Asia. The methodology used in these studies has been qualitative, quantitative or mixed. To collect the information, questionnaires, surveys, knowledge tests and specific instruments were used to evaluate the students' experience. A summary of the articles is presented in (Table 3).

Common themes found in the studies

Of the 13 selected studies, 28 findings were identified, which answered the research question. They were classified into 3 categories: 1) Improvement in Academic Performance and Clinical Skills; 2) Student Satisfaction, Motivation and Engagement; and 3) Impact on Learning Continuity and Flexibility. In terms of the total number of findings identified, they obtained a relative weight of 35.7%, 28.5% and 35.7%, respectively. In each of them, all the corresponding aspects mentioned in the articles were included (Table 4).

Improved Academic Performance and Clinical Skills

This category covers advances and progress in the understanding and application of theoretical and practical knowledge in the clinical field. It assesses how students or professionals are developing and perfecting their academic and clinical skills through different games such as Second Life (9), Psychiatric Hat (10) and Neurospeed (11), online (12-13) and digital courses (14), training OSCEs (15), videos of epileptic and psychogenic seizures (16), practical ultrasound classes and practical ultrasound workshops (17-18), virtual patient interviews (19) and the Mosaico web platform (20). We highlight the use of immersive technologies, this includes the use of simulations and innovative technologies to offer a closer and more effective learning experience, which have shown an increase in the ability to perform procedures and to use the acquired information effectively in the clinical environment.

Student Satisfaction, Motivation and Engagement

This category examines how educational tools and strategies, especially technologies, impact students' perception, motivation, and engagement in their learning process. This approach seeks to evaluate the effect of educational technologies and other methods on students' overall experience, their willingness to learn, and their involvement in academic activities. The increase in student satisfaction is evidenced through their evaluations of the new technologies implemented. On the other hand, motivation is reflected in the perception of usefulness they find in the use of these tools, which drives greater commitment, improves self-confidence, and strengthens learning through supervised practice and real cases. This is reflected in various studies such as the use of online courses to learn renal semiology, where students showed significantly greater satisfaction through virtual training dynamics, within a blended teaching instructional design (13). This was also evident in the digital course on epileptogenic terminology, where students showed high satisfaction and a 90% participation rate (14).

To continue with this analysis on the impact of technologies in education, it is important to highlight other studies that also reinforce the effectiveness of these resources. Regarding the use of virtual agents, the feedback was positive regarding pedagogical utility, realism, and enjoyment, showing acceptance of these technologies in their training (19).

Regarding the use of games, students enjoyed and would recommend the gamified type of training – taking the dynamics of a game to apply it to other contexts (21) – evidenced in the Psychiatric Hat game (10). Regarding Neurospeed, the study shows that it has improved short-term learning, student satisfaction and motivation, and has facilitated more interactive and autonomous learning (11). And finally, regarding the Second Life game, it is shown that its use improved students' perception and their academic results (22).

Table 3. Summary of selected studies.

Author	Objective of the study	Study design	Participants	Information gathering	Findings
Rudolphi et al. (Spain, 2023)	To evaluate Second Life game outcomes, student perceptions, and possible differences between participant subgroups in two different editions.	Quantitative (Quasi-experimental)	300 medical students	Cognitive load survey, perception questionnaire, pre- and post-exposure knowledge tests	The teams achieved good results in semiology, with averages of 74.2% in individual tests and 71.6% in group tasks, with no significant differences between the two. A moderate cognitive load was observed for the use of Second Life (3.6 and 3.7), reading presentations (4.3) and a high engagement in the weekly tests (6.1 and 6.3). However, there were criticisms regarding the ease of use of Second Life and connectivity problems. Long-term knowledge retention decreased (correlation coefficients of 0.316 and 0.288 in post-exposure tests).
Mastour et al. (Iran, 2023)	Comparing student learning outcomes between face-to-face and online learning methods	Quantitative (Cross-sectional)	126 medical students	Multiple choice online exam system with additional security measures, in-person multiple choice tests and online data collection through a university platform	Online courses showed significant improvement in theoretical semiology scores ($P < 0.001$), while no significant differences were observed in practical outcomes between online and face-to-face education ($P = 0.149$). This suggests that online education has been effective in improving students' theoretical understanding.
Jadue et al. (Chile, 2023)	To compare the levels of achievement in anamnesis skills of two cohorts of medical students in in-person and online semiology training OSCEs	Quantitative (Cohort)	183 medical students	OSCE Blueprint adapted to online assessment, assessment guidelines by station	The 2020 cohort showed significantly higher scores for history taking of diarrhea, cough, and knee pain, with clear differences from 2019 ($p < 0.0001$). Nonparametric tests indicated that the median scores in 2020 were higher. This validates the use of telesimulation and TeleOSCE as effective tools for teaching history taking skills to third-year students.
Birca et al. (Canada, 2021)	To assess the ability of different health professionals and medical students to distinguish between psychogenic non-epileptic seizures (PNES) and epileptic seizures (ES) using recorded seizure videos	Quantitative (Cross-sectional)	77 medical students, 82 neurologists, 18 epileptologists, 70 neurology residents, 31	Psychogenic non-epileptic seizure (PNES) or epileptic seizure (ES) classification questionnaires.	There were no significant differences between professionals and students in the agreement with the gold standard in PNES (69.1%) and ES (58.5%) ($p = 0.06$). Epileptologists achieved a higher diagnostic accuracy (AUC of 95%) compared to medical students (48%). An ANOVA analysis

			residents of other specialties, 27 emergency physicians, 116 nurses, 19 psychiatrists, 34 EEG technologists.		showed significant differences between professionals and students ($p \leq 0.001$), with significant results between several groups according to the post hoc test.
Corrêa et al. (Brazil, 2022)	Evaluate medical students' perceptions of implementation of ultrasound in the medical career.	Quantitative (Cross-sectional)	33 medical students	Simple interviews and structured questionnaire with closed questions, previously tested with 12 multiple choice questions based on the Likert scale, each with five options: totally agree, partially agree, neutral, partially disagree and totally disagree.	The use of ultrasound improved clinical skills and reinforced prior knowledge in 88% of cases. In addition, 97% of students expressed interest in participating in more practical ultrasonography classes, highlighting its usefulness in both improving physical examination and knowledge of human anatomy (91%).
Zamberg et al. (Switzerland, 2021)	To assess medical students' perception and satisfaction regarding an online learning activity on renal semiology.	Quantitative (Quasi-experimental)	141 second-year medical students and 17 fourth to sixth-year medical students.	Validated online survey, comprising questions answered using a 10-point Likert scale and an open-ended qualitative question.	Students in grades 4-6 showed higher satisfaction with online activities (mean 8.7 vs. 7.3, $p < 0.001$), greater clarity of objectives (mean 9.6 vs. 7.7, $p < 0.001$), and better attainability of objectives (mean 9.8 vs. 7.3, $p < 0.001$). Case-based activities were especially useful for advanced students within a blended instructional design.
Clément et al. (France, 2020)	To evaluate the benefit of a Psychiatric Hat Game session for learning psychiatric symptoms in third-year medical students.	Quantitative (Cross-sectional)	166 medical students.	Pre- and post-assessment of knowledge (multiple choice questions) and a satisfaction survey.	Knowledge scores were significantly higher after using games (+28.6%, $p < 0.001$), and this improvement was maintained for 3 months (+18.9%). Student satisfaction was high, and they would recommend game-based training, highlighting the potential of gamification in semiology learning.
Paternain et al. (Spain, 2019)	To evaluate the effectiveness of practical ultrasound workshops for the acquisition and consolidation of semiology learning aimed at third-	Quantitative (quasi-experimental)	352 medical students.	Pre- and post-assessment of knowledge (multiple choice questions).	Ultrasound workshops showed a significant improvement in test scores (+28.6%, $p < 0.01$) and in students' confidence in interpreting images (from 3.39/10 to 6.28/10) and handling

	year medical students.				equipment (from 3.73/10 to 6.51/10, $p < 0.01$). This validates the usefulness of these workshops in teaching ultrasound semiology.
Dupuy et al. (France, 2020)	To evaluate the effectiveness of a virtual agent (VP) in training medical students to conduct psychiatric interviews for diagnosis, as measured by semiology extraction and empathic communication	Quantitative (Quasi-experimental)	35 medical students.	Emotional recognition software, debriefing to collect experience and final evaluations.	Students improved their skills in identifying depressive symptoms in virtual patients, and the emotional recognition software favored the development of empathic skills. Scores in semiology were lower than in empathy ($p < 0.001$), and there were significant differences according to specialty, with better results in psychiatry than in neurology. Disgust showed a significant correlation with errors and scores in MCQs ($r = -0.46$, $p = 0.034$).
Von Wrede et al. (Germany, 2023)	Develop and design a digital course according to the Flipped Classroom Model (ICM) that supports the training of medical students in the fundamentals of epileptogenic terminology.	Quantitative (Quasi-experimental)	381 medical students.	Student satisfaction was assessed by a questionnaire using a four-point Likert scale and a final quiz with multiple-choice questions.	Students showed high satisfaction (90%) with the digital course, highlighting the effectiveness of clinical videos to teach semiology and analysis of epileptic seizures. However, the exams did not reflect differences between the groups with and without access to the digital course, probably due to the lack of specific questions in the tests.
Zeidan et al. (France, 2022)	To evaluate the effectiveness of a game called "Neurospeed" for learning the semiology of neurological syndromes.	Prospective observational study.	199 medical students.	Evaluation with multiple choice questions before and after the sessions, and collecting student opinions through a satisfaction survey.	The use of Neurospeed improved short-term learning, satisfaction, and motivation of students. MCQ scores increased from 6.13 to 8.03 ($p < 0.001$), with more students achieving scores above 10 after using the game (33.1% vs. 19.6%, $p < 0.001$). However, it is suggested to combine this tool with other strategies to improve long-term retention.
Rudolphi et al. (Spain, 2021)	Evaluating student perception and impact on learning through a competitive game in Second Life for teaching undergraduate radiology	Quantitative (Quasi-experimental)	52 third-year medical students.	Individual multiple choice tests, cognitive load assessment, an experience questionnaire, and a post-exposure knowledge test .	Using "League of Rays" in Second Life improved students' perception and academic results in semiology, with significant differences ($p = 0.009$) in post-exposure tests between participants and non-participants.

Guínez et al. (Chile, 2021)	Describe the design and development of a web platform created to strengthen the CCS model.	Qualitative (Phenomenological)	100 medical students.	Laboratory tests, performance assessments, teacher monitoring, Business Process Modeling and Notation (BPMN), electronic recording and collaborative debriefing	The MOSAICO platform enhanced collaborative and active learning during the pandemic, optimizing distance education and facilitating the development of clinical skills in a safe environment. It was also useful for the management and evaluation of educational resources.

Table 4. Classification of the influence of teaching medical semiology on medical students.

Improved Academic Performance and Clinical Skills	• Significant increase in the acquisition of theoretical knowledge (7) • Increase in scores obtained in theoretical evaluations (5) • Improvements in the application of practical knowledge (4) • Significant improvement in theoretical knowledge and diagnostic skills (4) • Greater improvement in clinical skills and physical examination (4) • Increased ability to recognize and diagnose clinical conditions (3) • Greater incorporation of immersive technologies to improve theoretical and practical understanding (3) • Increase in effective feedback from the use of technology (2) • Increase in the ability to relate various subjects (1) • Improvement in the collection of semiological information during the interview (1)
Student Satisfaction, Motivation and Engagement	• Enhancement of positive perception on the pedagogical utility and realism of the technological tools used (8) • High satisfaction reported by students when using technologies such as games and online platforms (5) • Increased motivation among students to use technologies, such as online platforms (5) • Greater sense of usefulness on the part of students regarding the use of technologies (4) • Improved motivation through continuous feedback and evaluation (4) • Increase in technological accessibility in students (3) • Improving students' technological skills (3) • Greater commitment and improved self-confidence through supervised practice and real cases (3)
Impact on Learning Continuity and Flexibility	• Increased flexibility in assessment methods (4) • Greater support for autonomous learning (4) • Expanding access to educational resources through online platforms (3) • Increased active learning through virtual platforms (3) • Strengthening collaborative learning through virtual platforms (3) • Improving learning continuity during the COVID-19 pandemic (3) • Reduction of geographical barriers to learning (3) • Increase in learning adapted to the student's time (2) • Improvement in collaborative learning (1)

* The total number of articles in the systematic review that address the topics presented are specified in parentheses at the end of each "(X)".

Impact on Learning Continuity and Flexibility

This category assesses how different educational methods and tools have influenced students' ability to continue and adapt their learning in various contexts. It focuses on how the flexibility of teaching and assessment methods, along with the accessibility of resources and platforms, affect the continuity of learning and adaptation to individual students' needs. Within the methods and tools we have flexibility in assessment, access to online resources, active and collaborative learning that facilitate adaptation and educational continuity, especially during the pandemic, overcoming geographical and personal barriers.

The impact on learning continuity and flexibility has been strengthened with the implementation of various educational technologies. A notable increase in the flexibility of assessment methods and greater support for autonomous learning have been key to adapting to students' needs, as reflected in the Second Life study, where online assessments and competitive tests within the game were used, offering flexibility in time and space for assessment (22). Another study compares face-to-face and online assessments, where the latter allow remote completion and are more versatile, suggesting that online technologies may have contributed primarily to improving theoretical understanding (12). Continuing with flexibility, in a 2021 research where videos and questionnaires were used as assessment tools, it was shown that this is a more flexible and accessible method to assess students' understanding at different times (16).

Furthermore, the expansion of access to educational resources and active learning through online platforms have enhanced both collaborative learning and student participation, especially during the COVID-19 pandemic, by reducing geographical barriers and ensuring the continuity of the training process, which was evidenced by using the MOSAICO web platform that has improved collaborative and active learning, facilitating distance education, and optimizing the evaluation and management of resources (20). In turn, the use of virtual platforms has allowed for learning that is more adaptable to students' time.

4. Discussion

The review carried out on the influence of technologies in the education of medical semiology yielded multiple important findings that highlight the positive impact of these tools on the comprehensive training of medical students. Among the main instruments, an improvement in the academic performance and clinical skills of students was observed, with 7 of the articles mentioning a significant improvement in theoretical knowledge and diagnostic skills, while only one talks about the increase in the ability to relate various interdisciplinary subjects (Birca et al., 2021).

Another important finding is the increase in student satisfaction, motivation, and engagement when using technologies in their teaching, where four articles talk about the high satisfaction reported when using technologies such as games and online platforms and another three of the articles show an increase in engagement and improvement in self-confidence through supervised practices and real cases. An impact on the continuity and flexibility of learning is also evident. Through various tools, barriers such as the pandemic were broken down to allow continuous teaching without disruptions (Guínez et al., 2021). The consistency of the results obtained among the thirteen articles that were reviewed and used in this research was generally high. Most of the studies reflect the benefits that come from semiological education through technology, although some variations were observed due to the different magnitudes, types of studies, characteristics of the participants, and types of technologies analyzed.

On the other hand, within the evaluation of biases, various results were found on the risk of presentation of these that vary from low to severe. Of the 7 quasi-experimental studies, evaluated with the ROBINS-I tool, 2 presented low risk, 3 moderate risk and 2 severe risk, the latter being the studies: "A team-based competition for undergraduate medical students to learn radiology within the virtual world Second Life" and "A Web Platform (MOSAICO) to Design, Perform, and Assess Collaborative Clinical Scenarios for Medical Students: Viewpoint".

Regarding the other studies, using the NIH-tool, it was found that all of them lacked justification for sample size and assessment at multiple points in time, in addition to not providing sufficient information on the blinding status of the evaluators and the presence of adjustment for confounding variables that may generate bias. On the other hand, all the studies effectively met the other criteria of the tool, having a clearly formulated research question, a clearly specified and defined study population, a participation rate of at least 50%, measurement of exposures before measuring the results, a time frame sufficient to show an association (in the studies where the criterion is applicable), clearly defined and valid outcome measures. Most complied with examinations of different levels of exposure and loss of follow-up less than 20%. Based on this, a low risk of bias exposure can be noted in most of the studies in the systematic review, with 8 of the 13 studies meeting a low risk of bias exposure, not being exempt from the lack of adjustment of confounding variables and justification of the sample.

The results of the review directly respond to the objectives initially set, demonstrating that technologies are positive tools to improve semiological education in medical courses. The results support the hypothesis that technology in this educational field expands learning opportunities and skill development by making more clinical cases accessible and homogenizing practical experiences among students, aligning with existing literature that demonstrates the benefits of using technologies in medical education in general.

Strengths and Limitations

Among the strengths of this systematic review is the diversity of sources included, which provide a complete and comprehensive view of the impact that technologies can have on medical semiology education. In addition, multiple restriction criteria were included to strengthen the validity and confidence in the findings found and a rigorous evaluation of biases was carried out to demonstrate the internal validity of each article. However, some methodological limitations were also identified, such as the existence of publication bias since the studies published on the subject are generally those that provide positive results. In turn, the heterogeneity of the study designs, the various technologies analyzed and the populations studied in the various articles may affect the generalization of the results obtained.

Future research

It is important to consider longitudinal studies for future research, in order to evaluate the long-term use of technologies in semiology education. It is also suggested to carry out comparative studies between different types of technologies to identify which are more effective and significant in the professional development of students. It is also recommended to analyze the implementation of technologies used in medical semiology teaching individually for the theoretical and practical components. These future investigations will have a significant contribution to the improvement of medical education, allowing the optimization of the use of technologies to benefit students and future doctors.

Recommendations

The findings of this systematic review are important for the education of medical semiology. The implementation of various technologies is suggested to improve teaching in this field. The use of simulations and technological applications are key to training students in a comprehensive and complete manner. Below, in Table 5, you will find a summary of the recommendations.

Table 5. Recommendations for the use of technologies in medical semiology teaching.

Integración de tecnologías	Use of simulations, interactive applications, activities with simulated patients, among others.
Teacher training	Provide optimal training to teachers on the use of technologies to maximize the medical education of students.
Longitudinal studies	To evaluate long-term effects.
Comparison of technologies	Identify which technology is most effective and positive for semiological teaching.
Skill development	Study the influence of technologies in practical and theoretical fields.

Integration of technologies

The use of simulations, interactive applications and activities with simulated patients is key to improving the teaching of semiology. These tools allow real clinical situations to be recreated in a controlled manner, facilitating the acquisition of diagnostic and therapeutic skills in a safe environment. In addition, these technologies provide students with the opportunity to practice multiple clinical scenarios without the limitations that exist in the real context, contributing to a more homogeneous and repeatable experience among all students.

Teacher training

The effectiveness of technologies in learning depends largely on the degree of familiarity of teachers with these tools. Therefore, it is essential that instructors receive adequate training on how to use these technologies optimally to support student learning. This includes not only the technical handling of the platforms and simulations, but also the pedagogical integration of them into the curriculum, so that teaching is more dynamic and adapted to student needs.

Longitudinal studies

In order to assess the long-term impact of technologies in the teaching of medical semiology, it is essential to conduct longitudinal studies. These studies will allow us to examine how theoretical and practical skills are developed and maintained over time, and whether the technologies used effectively contribute to the performance of future health professionals. The information derived from these studies will help to adjust and improve the use of technologies in teaching, ensuring that their implementation has long-lasting effects.

Comparison of technologies

As different technological tools are integrated into medical education, it is important to identify which ones are the most effective. This requires conducting comparative studies that evaluate different technologies, such as simulations, online learning platforms or

educational games, to determine which have the greatest impact on the acquisition of knowledge and skills. This approach will allow for optimizing resources and selecting the most appropriate technologies for the specific educational needs of semiology students.

Development of practical and theoretical skills

Technologies should not only focus on improving students' theoretical knowledge, but also on strengthening their practical skills. The development of competencies in semiology, such as performing physical examinations and interpreting clinical signs, can be significantly enhanced through the use of simulations and interactive technologies. These tools allow for immediate and accurate feedback, contributing to the improvement of clinical skills essential for medical practice.

5. Conclusions

- The use of technologies in the teaching of medical semiology corresponds to a valuable resource, which has a positive influence on the teaching-learning process.
- The findings show an improvement in the students' academic and practical performance, as well as their satisfaction and motivation.
- Technology enables comprehensive and holistic professional training that enables future doctors to face the challenges of the 21st century.

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Annex 1. Bias risk assessment table

Reference	**22**	**12**	**15**	**16**	**17**	13	10	18	19	14	11	9	20
NIH-TOOL (% "Yes" responses due to caution regarding risk of bias)		64.29	71.43	71.43	50		64.29				64.29		
ROBINS-I	Low					Low		Medium				Serious	

Annex 2. Description of the tools used for learning

Second Life (8, 21)

Second Life is a 3D virtual world used in education, especially in medicine, where students interact through avatars. On this platform, the game "League of Rays" allows radiology students to learn competitively and collaboratively, improving their knowledge and skills through activities and tests, which has shown a positive impact on their academic results.

League of Rays (8, 21)

"League of Rays" is a competition game created in 2015 for medical students on Medical Master Island, so that they could learn anatomy and radiological semiology in a more playful way.

OSCE (14)

OSCEs (Objective Structured Clinical Examinations) are tests used in clinical practice to assess health students' skills in dealing with different situations that may arise in their professional lives. OSCEs are based on a series of stations planned in a structured manner to objectively assess various important skills that students should have when facing different situations.

Psychiatric Hat Game (9)

The "Psychiatric Hat Game" is based on a deck of cards designed especially for teaching psychiatric semiological terms in a more playful way. Each card has a pathology, sign or symptom written on it and the students must define what is written so that the rest can guess. It is a fun teaching method that is different from the traditional one.

Neurospeed (10)

The "Neurospeed" game is an educational tool designed to help medical students learn neurological semiology in a fun and active way. Participants receive cards with neurological symptoms or signs and, upon identifying combinations that indicate a syndrome, they must respond quickly to describe the syndrome and its characteristics. Through repetition and the use of cards with distractors, Neurospeed stimulates memorization and diagnostic reasoning, allowing students to improve their understanding of neurological semiology in the short term. It is a fun and different teaching method from the traditional one, based on the "Psychiatric Hat Game".

MCQ scores (9, 10)

In the Neurospeed game, MCQs (Multiple Choice Questions) are used to assess students' learning before and after the game session. These questions cover topics in neurological semiology and allow the impact of the game on knowledge retention to be measured. Students answer a 20-question quiz before starting the game and then repeat it at the end of the session, allowing their initial and final scores to be compared.

MOSAIC (19)

"MOSAICO" is a web platform used to evaluate and design collaborative clinical scenarios for medical students. This platform has 4 modules: educational design, student collaborative design, collaborative simulation and finally collaborative debriefing.