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MEDICAL CURRICULUM IN THE DIGITAL AGE: A CRITICAL ANALYSIS OF THE BRAZILIAN REALITY

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Abstract: Rapid technological evolution has had a significant impact on medical training, presenting new challenges and opportunities in health education. This study aims to critically analyze the integration of technologies in the curricula of medical courses in Brazil, highlighting the urgent need for modernization. To achieve this objective, an integrative study was carried out, combining different literature review methodologies. The analysis followed a qualitative approach, based on a narrative review and using the inductive method. The results indicate that, despite technological advances, Brazilian medical education remains rooted in traditional models, highlighting the lack of effective strategies to integrate theory and clinical practice mediated by technologies. The importance of training Brazilian students to critically analyze online information, use technologies ethically and understand their impact on the doctor-patient relationship is highlighted. It is recommended that these skills be incorporated as essential curricular components in Brazilian medical training.

Keywords: Medical Technology; Medical Education; Curriculum; Educational Innovation; Medical Training.

INTRODUCTION

Technological developments have profoundly transformed medical practice in Brazil, introducing tools such as artificial intelligence, big data, virtual reality and connected devices. These innovations expand the possibilities for diagnosis, treatment and monitoring of Brazilian patients, promoting greater efficiency and accessibility in health services in Brazil. However, although resources such as telemedicine are present in current Brazilian medical practice, most Brazilian medical schools still do not adequately prepare Brazilian students to use them. Analyses of curricular proposals from Brazilian medical education institutions indicate that the practice of technology-mediated diagnosis and intervention remains poorly disseminated in the curricula of Brazilian medical schools.

The rapid technological transformation has not been accompanied proportionally by the curricular structure of medical courses in Brazil. Although the introduction of technological innovations in medicine has faced historical resistance in Brazil, understanding and integrating this articulation is fundamental during Brazilian academic training, as it directly impacts the work of health professionals (Oliveira *et al.*, 2020). Training, in this scenario, is crucial to strengthening the effectiveness of the provision of services integrated into the health ecosystem in Brazil (Silva; Silva, 2024).

Currently, there are countless technological resources linked to medical practice, including the Internet of Things (IoT), personalized applications, *dashboards*, *wearables*, 3D printing and diagnostic tools, virtual reality, the application of Artificial Intelligence (AI), digital phenotyping, *chatbots*, *big data*, robotics for drone work and telesurgery, telecare booths, among others, as Silva and Silva (2024) point out. These resources constitute an ongoing revolution, characterized by the digital health era, in which daily solutions emerge on an exponential scale, making preparation an educational responsibility of those who train in the field.

The most recent update of the National Curriculum Guidelines (NCGs) for undergraduate medical education in Brazil was established by Resolution No. 3 of the National Education Council (CNE), dated June 20, 2014. Considering the rapid advance of technologies, it can be seen that, a decade after their publication, the Brazilian DCNs have significant gaps with regard to the integration of technologies in medical training, treating them superficially as resources that contribute

to the incorporation of new medical practices, without praising their integration as a discipline and practice necessary for current medical training in Brazil. Although it covers general aspects of computerization in Brazilian health, it does not comprehensively address the technological advances currently applied to medical practice, leaving the organization of the curriculum to the institutions, which points to the urgency and unacceptability of updating the DCNs. The lack of a comprehensive approach to technological advances in Brazilian medical practice leaves it up to the institutions to organize the curriculum, which can lead to disparities in the training of doctors, since Higher Education Institutions (HEIs) are largely crystallized in traditional teaching (Gorges; Andrade, 2018). It is essential that the DCNs establish clear and objective guidelines for the integration of technologies in Brazilian medical training, ranging from the use of digital tools in teaching to the application of technologies in clinical practice, such as telemedicine.

With the advance of technology in Brazil, in 2016 the Ministry of Health (MS) published a new version of the National Health Information and Informatics Policy (PNIIS), with the aim of promoting the innovative, creative and transformative use of Information and Communication Technologies (ICTs) in order to improve health work processes and thus result in an articulated National Health Information System (SNIS), which produces information for citizens, management, professional practice, knowledge generation and Brazilian social planning.

Among the reflections, the PNIIS raises concerns about the lack of professional qualifications in this area in Brazil and the importance of aligning the country with international actions and strategies in the field of health ICTs. As guiding elements, the PNIIS allocates themes such as: the Access to Information Law (LAI), Electronic Government (e-Gov) policy, e-Health, which includes the Electronic Health Record (RES), management of the PNIIS and staff training in content related to the area of health information and informatics in undergraduate and postgraduate courses (MS, 2016).

Tools such as artificial intelligence, telemedicine and virtual reality have expanded the possibilities for diagnosing, treating and monitoring patients, making them essential for health promotion. However, the approach to technology in medical education in Brazil remains restricted, often limited to the use of computerized systems for hospital management and communication between health professionals. This limited vision ignores the transformative potential of technologies in medical practice, restricting their use to support tools, such as the online classroom, rather than exploring their potential in the application of medical practice, such as online consultations. Given this scenario, there is an urgent need to revise and modernize the Brazilian curriculum so that future doctors develop skills that enable them to use technological innovations critically and efficiently in their professional practice. The World Health Organization (WHO) also recognizes this fact and encourages countries to organize their policies, methods, standards and good practices for the use of technology in order to improve the quality of and access to health services - an area that the WHO calls e-Health (MS, 2016).

The lack of debate and practical application of technologies in medical training in Brazil highlights the need to reflect on the convergence between curriculum and technological innovation in the Brazilian context. This study aims to critically analyze the integration of technologies into the medical curriculum in Brazil, emphasizing the urgency of its modernization in the Brazilian context. Using a mixed-methods approach, it investigated

the gaps in the current training of Brazilian doctors and the opportunities for incorporating technological innovations to improve teaching and clinical practice in Brazil. It is hoped that this analysis will contribute to the development of educational strategies that prepare Brazil's future doctors for an increasingly digital and interconnected healthcare environment.

METHODOLOGICAL PATH

This study adopted a mixed approach, combining a systematic review of the literature with a qualitative exploratory study, with the aim of critically analyzing the integration of technologies into the medical curriculum in Brazil.

The systematic review was conducted following the guidelines of the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA), which guides the preparation of systematic reviews in the health area. The search was carried out in the SciELO Brazil database on February 26, 2025, using the terms "Curriculum", "Medicine", "*Curriculum*" and "*Medical*", defined from the Health Sciences Descriptors (DeCS) and combined with the Boolean operators AND and OR.

The inclusion criteria covered published studies relating the variables "curriculum" and "medicine" in the Brazilian context, with no restrictions on the type of publication. Although no time filter was applied, the publications selected were concentrated between 1997 and 2019. Documents that did not meet the scope of the study or were duplicated were excluded.

The initial search resulted in 18 studies. After removing duplicates and screening the titles, 7 publications were selected for reading the abstracts. Of these, 6 were excluded because they did not directly address the issue of technology in medical training. Only one publication, *'Mapping the different methods adopted for diagnostic imaging instruction at medical schools in Brazil'* by Chojniak et al. (2017), was included in the qualitative analysis. Although it does not deal directly with the curriculum, this study includes reflections on the impact of technological advances applied to medical practice in diagnostic imaging teaching.

To complement the findings of the systematic review and deepen understanding of the integration of technologies in medical training, a qualitative exploratory study was carried out. We used the content analysis proposed by Bardin (2006), which comprises three phases.

1. Pre-analysis: organization and systematization of the material collected, including scientific publications and relevant institutional documents, such as those of the Brazilian Association of Medical Education, the Ministry of Education and the Federal Council of Medicine.

2. Exploration of the material: categorization of the data, identifying themes and patterns related to the integration of technologies in the medical curriculum.

3. Treatment of results, inference and interpretation: critical analysis of categorized data, allowing the synthesis of information and the elaboration of reflections on the gaps and opportunities in Brazilian medical training.

The choice of the inductive method, as described by Marconi and Lakatos (2010), allowed generalizations to be made based on specific observations, expanding knowledge on the subject and highlighting the need for curricular modernization to incorporate technological innovations in the training of future doctors in Brazil.

This methodological approach provided a comprehensive and well-founded understanding of the subject, combining the objectivity of a systematic review with the depth of exploratory qualitative research.

BRAZILIAN MEDICAL EDUCATION: A HISTORICAL OVERVIEW

Medical training in Brazil has been shaped by a series of laws, ordinances and regulations aimed at guiding and regulating medical courses, ensuring the quality of teaching and its adaptation to the health needs of the population. The National Curriculum Guidelines (DCNs) advocate a generalist, humanist, critical and reflective education, outlining the profile of the expected graduate.

Below, based on normative institutions in the field, such as the Federal Council of Medicine (CFM) and the Ministry of Education and Culture (MEC), are the main regulations that have influenced medical education in Brazil:

1. **Creation of the First Medical Schools (1808)**: The foundation of the first medical schools in Salvador and Rio de Janeiro marked the formal beginning of medical education in the country.

2. **First Reform of Medical Education (1812)**: This reform extended the duration of the course from four to five years, seeking to deepen the training of future doctors.

3. **Free Education Law (1879)**: The enactment of this law allowed private initiative in medical education, expanding the range of courses and institutions on offer.

4. **Creation of the Federal Council of Medicine (1945)**: The institution of the CFM, together with the Regional Councils, established a new order in the medical category and introduced the first Codes of Medical Ethics.

5. **Resolution No. 8/1969**: This resolution of the Federal Education Council defined guidelines for the revision of traditional medical curricula, establishing a minimum curriculum for medical courses.

6. **National Exam for Medicine (1999)**: The Ministry of Education applied the first national exam for the Medicine course, with the aim of assessing the quality of the teaching offered.

7. **National Curriculum Guidelines (2001)**: Approved in 2001, the DCNs guided medical training based on competencies and skills necessary for professional practice.

8. **Updating the DCNs (2014)**: The revision of the DCNs in 2014 sought to align medical curricula with the contemporary demands of society and the Brazilian health system.

These regulations reflect the evolution of medical education in Brazil, with ongoing efforts to improve the training of health professionals and meet the emerging needs of the population. It can be seen, however, that the structure of the medical curriculum presents challenges in its updating, often remaining based on fragmented disciplines and showing resistance to change. Although the DCNs emphasize the importance of integrating content, the practical incorporation of technologies into medical training is still limited. The COVID-19 pandemic has highlighted the viability of practices such as telemedicine in both care and education; however, their inclusion in undergraduate curricula remains restricted.

The DCNs for medical courses in Brazil were initially established by CNE/CES Resolution No. 4, of November 7, 2001, and later updated by CNE/CES Resolution No. 3, of June 20, 2014, which remains in force. These guidelines direct the curricular organization and training parameters of medical courses throughout the country.

CURRICULUM AND MEDICAL TRAINING

Law 12.871, of October 22, 2013, article 4, makes the operation of undergraduate medical courses subject to the CNE's DCNs. technical-scientific advance, influenced by the Flexnerian model, consolidated hospital-centric medical education, restricting the understanding of the health-disease process to biological factors. Although Abraham Flexner's model (1910) is globally recognized in medical training, its initial focus on basic disciplines is insufficient for the current scenario (Assunção *et al.*, 2024).

Faced with the need to improve medical training, various strategies to link educational institutions and the health system have been implemented over the years. Miguel and Páez (2006) have already pointed out the importance of learning environments that train students for the knowledge society, highlighting technology as a pillar for improving undergraduate and postgraduate education. The integration of disciplines, advocated by the authors, promotes interdisciplinary training and improves professional practice, recognizing the potential of technologies in medicine.

Telemedicine in Brazil, authorized on an emergency and temporary basis by Law No. 13,989, of April 15, 2020, during the COVID-19 pandemic, was comprehensively and permanently regulated by CFM Resolution No. 2,314, of April 20, 2022. This resolution details types, ethical-legal aspects and requirements for the practice of telemedicine, such as digital signature and continuing education, in line with the Code of Medical Ethics. Telemedicine is seen as a complement, not a substitute, for face-to-face care, with guidelines for documentation and data protection. Despite this, challenges persist and basic training in the use of technology is neglected, impacting on medical practice.

The World Medical Association (WMA) recognizes the fundamental role of ICTs in medicine, emphasizing the urgent need for a curriculum review in Brazil. Technological innovations have advanced rapidly, demonstrating significant clinical results, such as the incorporation of technologies in diagnostic imaging (Chojniak et al., 2017). However, medical training strategies and practices in Brazil are still limited, often relegating ICTs to a complementary role in face-to-face care or restricting their use to documentation and data protection guidelines. Given this scenario, it is crucial to recognize that, despite the persistent challenges and neglect of basic training in technologies, this issue cannot be ignored, as it directly impacts Brazilian medical practice. A curriculum review is therefore imperative to prepare future doctors for the digital age.

Initiatives such as the Alô Saúde program exemplify the use of ICTs to expand access to healthcare. In this context, educators, educational managers and public policy makers need to question how to orient doctors in training to this reality (CFM, 2018). After all, what the newly qualified doctor will do will be more difficult if they have not been adequately prepared. Programs such as Alô Saúde, which offer guidance, pre-clinical care, medical care and information by telephone, video call or chat, are already a reality in states such as Rio Grande do Sul and Santa Catarina, expanding access to existing public care.

In view of this, it is clear that the integration of technologies into medical training goes beyond the mere use of digital tools in teaching. It is imperative to develop students' ability to critically analyze the information available online, to use technologies ethically and responsibly, and to understand the impact of these technologies on the doctor-patient relationship. To this end, it is essential that technologies are incorporated as a discipline and practice in medical training, with speci-

fic content and practical activities. Integrating technologies into medical training is not just about keeping up with technological developments, but ensuring that future doctors are able to meet society's demands and provide quality, efficient care.

THE IMPACT OF THE DIGITAL AGE ON MEDICAL TRAINING

The integration of emerging technologies, such as teleconsultation, 3D printing and virtual reality, is crucial for contemporary medical training, although it faces challenges such as institutional barriers and a lack of training. The digital society demands that medical education not only uses technologies, but also instructs in their clinical use, as exemplified by innovative initiatives at the University of São Paulo Medical School (FMUSP) and the University of Passo Fundo (UPF).

FMUSP, with its Virtual Man project, demonstrates the potential of integrating computer graphics, 3D printing and virtual reality in learning anatomy, physiology and pathophysiology. This project promotes the construction of 3D digital models and animations that explain physiological and pathophysiological processes in an objective and clear manner, offering innovative resources for medical education (Wen, 2016).

UPF, for its part, has implemented the subject of Digital Medicine, which deals with current technologies and trends in the health field, with the aim of improving the quality of services provided by future doctors. This subject explores the different roles doctors will play in the future, including the use of artificial intelligence, 3D printing of orthoses and prostheses, augmented virtual reality, precision medicine and gene editing (UPF, 2022).

In addition, it was noticed that the magnitude of the situation can impact the quality of the doctor-patient relationship and limit the future doctor's ability to work with unknown demands, resulting in resistance, what Silva and Silva (2024) call "digital immaturity" - preconceptions and resistance to technology in the medical field emerging from the unknown. The subject cuts across different modules and can even be included as practice, whether in models such as PBL or traditional ones, in which the student has contact with the reality of the applicability of these resources, whether to work in a remote or less-assisted region, or even in large centers to provide care via telemedicine, for example.

Updating the curriculum is imperative in order to include specific subjects on the potential and limits of these technologies, preparing doctors for a digitalized scenario. The outdated DCNs and resistance to change (digital immaturity) demand an urgent review, with the inclusion of practical and theoretical subjects on ICTs, ranging from telemedicine to gene editing.

The current minister of education, in his speech, made it clear that inter-ministerial updates on medical residencies and medical courses are planned, which could be an agenda for updating the medical training curriculum. The content is not yet known for sure, but the news rekindles the need for updating in the area of health education, in other words, qualification in the training of medical professionals. The current version of the curriculum guidelines that guide medical courses throughout Brazil is now 10 years old. That's if we consider the revision of the document, since it was formulated in 2001, which undoubtedly puts us before the emerging need for curricular re-evaluation.

More objectivity, compulsory subjects and practices in medical care with technologies, interprofessional education for medical professionals who work with multidisciplinary teams are some of the strategies for a relevant curriculum in the knowledge society, which is fundamental for good medical training. The

Ministry of Health, based on the 2020-2028 plan for digital e-health strategies for Brazil, already foresees that the intervention of doctors through services that integrate technologies, such as telemedicine and telehealth, both public and private, will bring expected benefits from the action for citizens to the Brazilian health system (MS, 2020). To this end, the project plans to promote the training of health professionals, including undergraduate, specialization, master's and doctoral degrees in the area.

In addition, it is recognized that curricular models in some institutions have undergone changes following the establishment of defined policies, however, the movement is still very limited when compared to the reality experienced. For example, it wasn't until 2022 that the CFM recognized the regulation of telemedicine as a form of ICT-mediated medical services, by means of Resolution Nº 2.314. This is a significant delay compared to the movement and expansion of technological possibilities. After all, according to Chehuen Neto et al. (2019, 631), "students new to the medical course have expectations arising, for example, from the status that accompanies the profession", considering the new technologies that many already associate with telecare, either as something positive, if they are familiar with it, or negatively, if they are unaware of the practice (Silva; Silva, 2024).

Although some institutions have begun to modify their curricula, the slow adoption of technologies such as telemedicine highlights the need for an urgent review of the DCNs. The latest update, in 2014, treats ICTs superficially, neglecting their structuring role in medical practice. It is crucial to recognize the gap in the DCNs at that refers to the integration of technologies. The mention of ICTs for remote interaction and remote databases is insufficient, and it is necessary to go further and emphasize the importance of treating technologies as a discipline and practice in medical training. It is also crucial to recognize that the need for a comprehensive approach to technological advances in medical practice leaves the organization of the curriculum up to the institutions, which can lead to disparities in the training of doctors. It is essential that the DCNs establish clear and objective guidelines for the integration of technologies in medical training, ranging from the use of digital tools in teaching to the application of technologies in clinical practice, such as telemedicine. In other words, the integration of technologies in medical training is not limited to the use of digital tools. Students need to develop the ability to critically analyze the information available online, to use technologies ethically and responsibly, and to understand the impact of technologies on the doctor-patient relationship.

To this end, it is essential that technologies are treated as a discipline and practice in medical training, with specific content, practical activities and contextualized assessment. Doctors need to be trained for the future, or rather for the still invisible present. And the reality of medicine includes the integration of technologies into medical training. It's not just a question of keeping up with technological developments, but of ensuring that future doctors are able to meet society's demands and provide quality, efficient care.

The medical curriculum, a living organism, requires constant revision to keep up with the evolution of the knowledge society. The participation of students and teachers is fundamental for the implementation of new guidelines, which should include practical and theoretical subjects on ICTs, preparing doctors for the demands of the digital society. In this sense, recognizing the gap in the DCNs regarding the integration of technologies is crucial. After all, the mention of ICTs for remote interaction and remote databases is insufficient. We need to go further and empha-

size the importance of treating technologies as a discipline and practice in medical training, with specific content, practical activities and contextualized assessment. Medical training needs to prepare professionals for the future - or rather, for the still invisible present - and the reality of medicine includes the integration of technologies. It's not just a question of keeping up with technological developments, but of ensuring that future doctors are able to meet society's demands and provide quality, efficient care.

MEDICAL CURRICULUM: A PROPOSAL FOR DIGITAL INTEGRATION

Given this Brazilian scenario, five reflective points were organized for a curriculum review of medical courses in Brazil:

1. **Creation of specific subjects:** Include subjects that address technologies applied to health in Brazil, such as telemedicine, electronic medical records, artificial intelligence, health data analysis, among others.

2. **Integration of technologies in other subjects:** Using digital technologies as teaching and learning tools in all subjects on the course in Brazil, such as virtual simulations, distance learning platforms, virtual reality applications, among others.

3. **Developing digital skills:** Developing digital skills in Brazilian students that are essential for medical practice in Brazil, such as the ability to search for and analyze information in scientific databases, use electronic medical records, perform teleconsultations, among others.

4. **Ethics and responsibility in the use of technologies:** Address ethical and responsibility issues in the use of technologies in medical practice in Brazil, such as data security, patient privacy, the doctor-patient relationship mediated by technologies, among others.

5. **Clinical practice with technologies:** Include practical activities that allow Brazilian students to experience the use of technologies in clinical practice in Brazil, such as teleconsultations, monitoring patients using apps, using electronic medical records, among others.

In short, we believe that the revision of the curriculum of medical courses in Brazil is a fundamental step towards guaranteeing the training of Brazilian doctors who are prepared for the challenges of the digital age.

This being the case, the intention is to contribute, based on these reflections, to plans to renew the curriculum of the Faculty of Medicine in Brazil. After all, we live in the digital age, in which the technologies used in society's daily life have a direct impact on the daily life of Brazilian medicine, which has its scope of action and possibilities for intervention expanded.

FINAL CONSIDERATIONS

Medical training, like that of other health professionals in Brazil, must keep pace with technological developments in order to prepare professionals capable of facing the challenges of contemporary medicine. In this sense, the structured integration of technologies into the curriculum is essential to promote more efficient teaching in line with current needs. Consequently, further studies are needed to assess the impact and viability of these innovations in Brazilian medical education.

In addition, the inclusion of specific subjects focused on new medical technologies is a pressing need, as it allows professionals to use these tools with competence and responsibility. Furthermore, there is an urgent need to revise the curriculum to incorporate at least one subject dedicated to the integration of technologies in health promotion and in Brazilian medical practice. Although there have been advances in areas such as telemedicine, artificial intelligen-

ce and virtual reality, the modernization of the curriculum is still timid. In other words, the traditional teaching model, which is often fragmented, does not always facilitate the adoption of new methodologies, compromising the preparation of professionals capable of working in contemporary medicine.

In this context, it is important to recognize that the current DCNs already mention the use of ICTs in Brazilian medical education. However, it is considered that the mention of the use of technologies still occurs in a superficial way, that is, without integrating them as fundamental elements of current medical practice. Given this, and the significant technological advances in medicine in recent years, it is pertinent to argue that an update of the DCNs is necessary to reflect the demands of the digital age, thus encouraging institutions to incorporate emerging technologies into Brazilian medical education in a more robust and structured way.

In short, curriculum revision and the formulation of up-to-date public policies are imperative to ensure that, in the near future, Brazilian patients will be cared for by doctors who are trained for the contemporary technological reality. Thus, the integration of technologies into Brazilian medical practice must be emphasized in the curriculum structure, whi-

ch currently lacks a documentary emphasis on this aspect. Therefore, incorporating these elements into medical training will raise the quality of the training system, making the discussion about the medical curriculum and the digital age unavoidable and necessary.

Finally, it is necessary to emphasize that curricular revisions and public policies on the subject are essential in Brazil, since the current ones are outdated and insufficient for the current scenario. It is considered that technologies, if integrated into Brazilian medical training, raise the quality of the care system. It is therefore a topic of great importance for the reform of the Brazilian medical curriculum. It is a latent need. Therefore, it should be noted that updating the DCNs is urgent and unavoidable in Brazil. The latest update, in 2014, does not adequately address the integration of technologies into Brazilian medical training. The current DCNs treat technologies superficially, as mere support resources, and not as structuring elements of contemporary medical practice in Brazil.

Finally, it is recommended that in-depth discussions continue in order to promote an updated curriculum prepared to meet the needs of the professionals of the future, who will find themselves in an increasingly digitalized scenario in Brazil.

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