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ORIGINAL ARTICLE

Contribution of learning environments to the learning and development of competencies in Microbiology

Contribución de los escenarios formativos en el aprendizaje y desarrollo de competencias en Microbiología

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ABSTRACT

Background: Microbiological training for medical students is essential for developing the necessary skills to solve professional problems related to infectious diseases, antimicrobial resistance, and epidemic control.

Objective: to analyze the contribution of different training scenarios to the learning and development of microbiology skills in medical students.

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Methods: a qualitative-descriptive study with a pedagogical approach was conducted at the University of Medical Sciences of Holguín during the 2024 academic year, aimed to analyze the contribution of educational settings to the student training process. Theoretical methods included analysis-synthesis, inductive-deductive, historical-logical, and systemic-structural approaches. Empirical methods included documentary analysis of study programs and observation in student training settings.

Results: university settings in Microbiology provide a theoretical and practical foundation for the comprehensive training of future physicians. The first level fosters community prevention and health promotion; the second provides direct experience in the diagnosis and hospital management of infections, including biosafety and antibiotic resistance.

Conclusions: integrating microbiology into multiple educational settings strengthens the clinical, epidemiological, and research competencies of medical students, preparing them to respond to current health challenges.

MeSH: education, medical, undergraduate; Microbiology; competency-based education; students; programs; education, medical.

RESUMEN

Fundamento: la formación microbiológica en estudiantes de Medicina es esencial para el desarrollo de competencias necesarias en la solución de problemas profesionales relacionados con enfermedades infecciosas, resistencia antimicrobiana y control de epidemias.

Objetivo: analizar la contribución de los distintos escenarios formativos en el aprendizaje y desarrollo de competencias en Microbiología en estudiantes de la carrera de Medicina.

Métodos: se realizó un estudio cualitativo-descriptivo con enfoque pedagógico en la Universidad de Ciencias Médicas de Holguín, durante el curso académico 2024, orientado a analizar la contribución de los escenarios formativos al proceso de formación de los estudiantes. Se utilizaron métodos teóricos: análisis-síntesis, inductivo-deductivo, histórico-lógico, sistémico-estructural; empíricos: análisis documental de los programas de estudios y observación en los escenarios de formación de los estudiantes.

Resultados: los escenarios universitarios en Microbiología proporcionan una base teórica y práctica a la formación integral del futuro médico: el primer nivel fomenta la prevención y

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promoción comunitaria; el segundo, brinda experiencia directa en diagnóstico y manejo hospitalario de infecciones, incluyendo bioseguridad y resistencia antibiótica.
Conclusiones: la integración de la Microbiología en múltiples escenarios formativos fortalece las competencias clínicas, epidemiológicas e investigativas en estudiantes de Medicina, preparándolos para responder a desafíos sanitarios actuales.
DeCS: educación de pregrado en Medicina; Microbiología; educación basada en competencias; estudiantes; programas; educación médica.

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INTRODUCTION

The concepts of education and education as a process, understood as a social function, aim to form and develop individuals. Currently, educational systems apply and continue to seek models that meet the demands of training competent professionals. In this sense, the quality of general practitioner training is a global issue due to its importance in meeting the population's health service needs.[(1)] Therefore, the National Directorate of Higher Medical Education in Cuba, under the Ministry of Public Health (MINSAP), has taken on the challenge of graduating general practitioners sufficiently prepared to solve health problems.
through comprehensive medical care, a social requirement reflected in the current medical school curriculum.[(2)]

Training in Microbiology is a fundamental pillar of the medical curriculum, especially in contexts where infectious diseases represent a significant public health burden. In Cuba, the profile of the general practitioner demands not only theoretical and practical mastery of this discipline, but also its application in diverse educational settings that promote the development of clinical, preventive, and research skills.[(3)]

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From a dynamic perspective on microbiology education, the professional problems within this discipline constitute the guiding principle of the training process and acquire meaning in the diverse contexts where medical students develop their skills. The very propaedeutic-clinical nature of microbiology demands that these problems occupy a central place in its educational dynamics; thus, theoretical knowledge is articulated with the demands of professional practice.

The microbiological professional problems that guide the training of medical students reflect real and challenging situations that physicians face in their clinical practice. These problems, in addition to enabling the integration of theoretical and practical knowledge, prepare students to resolve complex situations related to microbiology in different healthcare settings.

Some examples of these professional problems include:

Infectious problems: febrile syndrome without localization; infectious syndrome with localization: infective endocarditis, lymphangitis, childhood exanthematous diseases, urinary tract infection, inflammatory lung diseases, influenza and other viral respiratory infections, central nervous system infections, skin and soft tissue infections; and emerging or re-emerging diseases: arboviruses, STIs, AIDS, pulmonary tuberculosis.[2]

These professional problems are not only fundamental to microbiological training, but they also allow students to develop critical skills: clinical thinking, decision-making, and problem-solving in real-world contexts. Furthermore, they foster the integration of microbiology with other medical specialties, such as: Internal Medicine, Pediatrics, Family Medicine, Gynecology and Obstetrics, Surgery, Urology, Ophthalmology, Otolaryngology, Dermatology, Orthopedics and Traumatology, and Public Health.

For some authors: "... teaching scenarios are understood as dynamic systems of interrelations between subjects and culture, as a historical, symbolic and subjective manifestation, discursively mediated".[4] Others state: "... the educational scenario is

established in a specific context, in which different events occur that serve as a framework for learning and has certain characteristics that allow for the optimization of the actions and activities carried out there, and define the relationships of the actors or protagonists who act and interact fulfilling different roles that they assume according to the level of participation in the educational process: teachers, students, among others. They constitute a process of educational situations consisting of analysis, decision-making and articulation, which specifies an organized proposal for a concrete project of educational action".[5]

University-level training settings in primary and secondary healthcare are strategic spaces for integrating competencies with professional practice. Their curriculum design demands strengthening clinical-microbiological diagnostic skills, antimicrobial resistance management, control of nosocomial infections, and participation in epidemiological surveillance programs.

Although descriptions of the curricular organization of Microbiology exist, few studies systematically evaluate how these settings influence the development of Microbiology competencies in medical students. Therefore, this study aims to analyze the contribution of different training settings to the learning and development of Microbiology competencies in medical students.

METHODS

A qualitative-descriptive study with a pedagogical focus was conducted in the Medicine program at the University of Medical Sciences of Holguín during the 2024 academic year. The study aimed to analyze the contribution of university, primary, and secondary healthcare training settings to the development of microbiology competencies in medical students. The design was based on document analysis and a critical review of specialized literature.

The following theoretical methods were employed:

- Analytical-synthetic: it was applied to analyze the components of microbiological training in the different training scenarios (university, first and second level of care) and to

synthesize how these spaces contribute to the development of Microbiology competencies in medical students.

- Inductive-deductive: to identify common patterns in how students develop competencies in Microbiology in different clinical contexts and to apply theoretical concepts of problem-based and competency-based medical education to the three training scenarios analyzed.
- Historical-logical: used to contextualize the evolution of Cuban medical education and the role of Microbiology within the medical curriculum, especially in relation to current curricula.
- Systemic-structural: to analyze the relationship between the three training scenarios (university, primary, and secondary care), considering them as parts of an integrated system that must guarantee the student's comprehensive training in Microbiology.

The analysis was developed within the framework of medical education in Cuba. It used the current curriculum for the medical degree as a reference and focused on the teaching of Microbiology from an integrative and multidisciplinary perspective.[2]

Empirical methods:

- Documentary analysis: this analysis considered curricular documents, methodological guides, and educational experiences published in indexed journals, as well as observations derived from teaching practice in subjects related to Microbiology in different educational settings.

A systematic review of official curricular documents and relevant scientific literature was conducted, along with a critical analysis of theoretical frameworks on competency-based education and educational settings. Practical examples of the application of Microbiology in the three educational settings -university, primary healthcare, and secondary healthcare- were also described.

Procedures

Initially, the key Microbiology content within the Cuban medical curriculum was identified. Subsequently, the characteristics and educational potential of each learning environment

were described, focusing on how these spaces promote the development of Microbiology competencies in students. The relationship between the learning environments, the social determinants of health, and their impact on the comprehensive training of general practitioners was systematized.

The data obtained were processed through thematic analysis and categorization of concepts, using a qualitative approach. Recurring patterns were identified regarding learning objectives, skills developed, and challenges faced by students in each learning environment.

RESULTS AND DISCUSSION

Document analysis and the application of theoretical and empirical methods allowed us to identify the fundamental characteristics, potential, and limitations of each training setting, as well as the systemic relationships between them. The findings are presented below, organized into three main sections.

Characterization of the training settings: the analysis of the literature and curricular documents allowed us to characterize each setting, not as isolated entities, but as components of a comprehensive training system.

The university setting constitutes the essential foundation for training in Medical Microbiology, where the basic content on the health-disease, promotion-prevention, and the epidemiological method. The main characteristics of this scenario are summarized in Table 1.

Table 1. Main characteristics of the university setting in microbiological training. Holguín University of Medical Sciences. 2024

Characteristics	Description
Pedagogical Approach:	Theoretical-practical
Key contents	Microorganisms, diagnostic techniques, antimicrobial

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	resistance, epidemiology
Developed skills	Laboratory management, interpretation of microbiological tests, critical analysis
Available resources:	Specialized laboratories, molecular diagnostic equipment, scientific literature
Associated competencies:	Microbiological diagnosis, clinical-laboratory correlation, critical thinking
Educational potential:	Research development, interdisciplinary integration

Source: analysis of study programs and scientific observation.

The primary care setting, comprised of polyclinics and family physician offices, represents an essential training space where primary healthcare, the family, and the community converge. The main characteristics of this setting are summarized in Table 2.

Table 2. Main characteristics of the Primary Healthcare setting in microbiology training. Holguín University of Medical Sciences. 2024

Características	**Descripción**
Pedagogical approach	Clinical-Care-Based
Key contents	Diagnosis and treatment of serious infections, antimicrobial resistance, control of nosocomial infections
Developed skills	Interpretation of antibiograms, management of critically ill patients, advanced biosafety measures
Available Resources:	Hospitals, clinical laboratories, multidisciplinary teams
Associated competencies	Management of infectious disease emergencies, evidence-based decision-making, care coordination
Potential education potential:	Real-world experience, interdisciplinary, ethical professional development

Source: Analysis of study programs and scientific observation.

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Relationships of articulation and complementarity: Using the systemic-structural method, it was identified that the training sequence is not linear but rather progressively integrated. The university setting, in Table 1, provides the theoretical and technical foundation, but the analysis reveals that its main limitation is the lack of immediate clinical application. This limitation is compensated for by the primary care setting, in Table 2, where it was found that students apply microbiological knowledge for the first time in real-world prevention and promotion contexts, developing community-based competencies. Finally, the analysis demonstrated that the hospital setting, in Table 3, consolidates and integrates all previous learning, focusing on complex diagnosis and the management of antimicrobial resistance. The transition between settings is guided by the problem-based approach, which acts as a unifying thread.

The analysis identified strengths and limitations, as well as common patterns in the challenges observed:

- University: Access to advanced technology (PCR, molecular diagnostics) was identified as a strength, while the difficulty in keeping content and equipment up-to-date in the face of rapid scientific advances was identified as a potential limitation.
- Primary care: The analysis revealed intersectoral collaboration and community work as its greatest strength, but also identified the potential restriction of limited infrastructure or diagnostic resources as a recurring limitation in the literature, which can affect the depth of learning.
- Secondary or hospital care: Its main strength is real-world experience and multidisciplinary work. However, the analysis highlights that the high workload and student turnover can hinder optimal faculty supervision.

Integration as a system: the central finding of the historical-logical and systemic analysis is that the effectiveness of microbiological training does not reside in each scenario separately, but rather in their coherent articulation. The study concludes that the training system is vulnerable to changes in the social determinants of health (entropy), but this vulnerability is mitigated through curricular integration and the use of real-world professional problems as a

central focus, ensuring the contextualization and relevance of the training in all three scenarios.

The university offers a unique environment that integrates theoretical training with specialized practice, providing access to laboratories equipped with advanced technology (microscopy, PCR, molecular diagnostics) where students master essential techniques such as microbial culture and Gram staining. This setting fosters critical thinking through clinical case analysis and evidence-based seminars, preparing future physicians for challenges such as interpreting laboratory results, selecting antibiotic therapies, and preventing nosocomial infections. Furthermore, the university facilitates participation in research projects on current issues such as antimicrobial resistance and vaccine development. The training process is guided by professors of general education courses and courses in the basic and basic-clinical cycles of primary and secondary care.[6,7]

The methodological approach to content is structured through an interdisciplinary framework that considers the social determinants of health for selecting professional problems and leveraging the potential of each discipline. This aims to integrate academic, professional, research, and outreach dimensions, thus ensuring comprehensive training to meet the challenges of contemporary medical practice.

The university setting provides the fundamental theoretical and practical foundations, particularly through specialized laboratories and active methodologies such as problem-based learning (PBL). These spaces promote critical thinking and the understanding of essential concepts such as microbial pathogenicity, antimicrobial resistance, and microbiological diagnosis. However, while this environment allows for technical mastery, it lacks the immediate clinical experience necessary to consolidate real-world diagnostic skills, something that is addressed later in other settings.[8]

The primary care setting presents itself as a privileged space for linking Microbiology with public health and community prevention.[9] In this context, students apply microbiological knowledge in real-world situations, participating in activities such as vaccination promotion, health education, and epidemiological surveillance. Interdisciplinarity and intersectorality are

distinctive characteristics that strengthen the future physician's ability to act from a population-based and preventive perspective.

At this level, medical students have their first direct contact with individuals, families, and communities, allowing them to interact with the most prevalent health problems. The approach encompasses: 1) promotion and prevention of epidemiological risks (water supply, food safety, nutrition, and basic sanitation); 2) maternal and child health and family planning; 3) immunization programs; and 4) treatment of common diseases; all using scientifically validated and socially acceptable technologies. This outpatient care focuses on the individual, the family, and their environment.[10]

The primary care polyclinic is relevant to microbiological training for multiple reasons:

- Enables the practical application of theoretical concepts through the identification of prevalent pathogens and the interpretation of diagnostic tests.
- Facilitates the development of clinical skills for the recognition of bacterial, viral, fungal, and parasitic infections.
- Emphasizes preventive measures such as vaccination, the rational use of antimicrobials, and health education.
- Promotes the integration of Microbiology with other disciplines (Epidemiology, Immunology, Pharmacology).
- Demonstrates the impact of infectious diseases on public health through epidemiological surveillance.
- Fosters multidisciplinary collaboration. In this context, the learning stakeholders include specialists in Family Medicine and other medical specialties, graduates, technologists, individuals, family members, the community, and members of other sectors.

The aspects described above represent potential benefits for the microbiological training of medical students.[11,12]

The hospital setting represents the culmination of the training process, where all acquired knowledge is integrated. This environment provides direct experience in the diagnosis and

management of complex infections, fostering the correlation between clinical findings and microbiological results. Furthermore, it allows students to become familiar with critical issues such as antimicrobial resistance and nosocomial infections, priority aspects in current global health concerns.[13]

While each setting offers unique potential, it also presents challenges. In the university setting, one of the main challenges is ensuring the constant updating of laboratory content and technologies to maintain their relevance in the face of scientific advances. At the primary care level, limitations in infrastructure and diagnostic resources may restrict the depth of microbiological learning. In the hospital, high student turnover and heavy clinical workload can hinder adequate faculty supervision.

However, the integration of these three scenarios allows us to overcome these limitations. Training scenarios should not be conceived as isolated spaces, but rather as interconnected parts of the same educational system. The progression from the theoretical to the clinical-community ensures that students develop a comprehensive understanding of Microbiology and its application in medical practice.[14,15]

This integrative approach is fundamental for preparing physicians capable of facing current public health challenges, such as the emergence of new infectious diseases, antimicrobial resistance, and epidemic outbreaks. Medical training must be centered on resilience to health crises, and Microbiology plays a central role in this preparation.[16]

The introduction of digital coordination technologies emerges as a fundamental tool for maintaining the cohesion of the training process, which implies constant feedback between academia and health services, thus ensuring the relevance of medical training in the face of contemporary epidemiological challenges.[17]

From a systemic perspective, the interrelation between the three training settings constitutes a coordinated system where the epidemiological training process is developed through interdisciplinary work, integrating the specific potential of each field to address the

social determinants of health as a cross-cutting theme in the identification and solution of professional problems.

This dynamic presents particular vulnerability to entropic processes due to the changing nature of the risk factors that shape these determinants, especially at the healthcare levels where epidemiological transformations are more frequent and intense. To guarantee effective training, the system requires continuous adaptation mechanisms that allow for: a) the ongoing updating of pedagogical strategies based on changes detected in clinical settings, b) the differentiated development of epidemiological competencies (theoretical, community, and hospital-based) according to each context, and c) the implementation of integrated evaluation systems that connect the three training areas.

Scientific contribution

It lies in the articulation and systemic analysis of the three training settings (university, primary care, and hospital) as an integrated pedagogical model for developing competencies in Microbiology. The study allows for the identification and characterization of the complementary role of each setting, demonstrating a comprehensive training that encompasses everything from theoretical foundations and community prevention to the specialized clinical management of infections.

CONCLUSIONS

The integration of training scenarios guarantees comprehensive, contextualized microbiological training oriented toward solving real professional problems, thus preparing future physicians for the complex challenges of contemporary clinical practice.

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Declaration of interests

The authors declare no conflict of interest

Authors' contributions

Lilianne Dominguez Céspedes: conceptualization, research, literature review, manuscript writing, database creation, and final version approval

Raysa Hernández Batista: conceptualization, methodology, project management, and final manuscript review and approval

Roberto Pérez Almaguer: conceptualization, methodology, and final manuscript review and approval