

Chang Liu, Ping He and Wei Zhao*

Evolution and reform of Medical Microbiology education in New Medical Science era

<https://doi.org/10.1515/gme-2025-0018>

Received July 18, 2025; accepted September 7, 2025;

published online November 19, 2025

Abstract

Objectives: Medical Microbiology is a cornerstone of medical education. Under the guidance of the “New Medical Science” concept, curriculum reform is imperative. This study aims to identify learning gaps, design innovative teaching strategies, and conduct rigorous evaluation of the reform effectiveness.

Methods: This study analyzed challenges in student courses and proposed innovations: updating course objectives; reconstructing content to integrate scientific thinking, One Health concepts, and infectious disease prevention; adopting a blended approach that combines lectures with discussions, foundational knowledge with cutting-edge research, and online with offline materials; and implementing a developmental, diversified evaluation system.

Results: The reforms proved highly effective. Students showed marked academic improvement, particularly in knowledge application, as well as enhanced critical and systematic thinking skills. Furthermore, their interest and ability in research grew, and they gained a deeper understanding of the key role of microbiological literacy in preventing and managing infectious diseases in clinical settings.

Conclusions: This innovative Medical Microbiology curriculum reform, guided by the “New Medical Science” paradigm, adopted a student-centered approach through content and pedagogical innovation. The success of this approach provides a valuable framework for transforming foundational medical education.

Keywords: Medical Microbiology; medical education; New Medical Science; One Health

Introduction

Medical Microbiology is a core foundational course in medical education, focusing on the study of pathogenic microorganisms related to medicine, their biological characteristics, pathogenicity, and immunity, as well as laboratory diagnosis, prevention, and treatment principles. The aim is to control and eradicate infectious diseases and related immune damage, thereby safeguarding and enhancing human health. The course is both theoretical and practical. Against the background of the frequent occurrence of emerging and re-emerging infectious diseases, there is an increasing global demand for clinical and public health personnel with expertise in infectious diseases. This underscores the pivotal role of Medical Microbiology within the broader framework of the medical curriculum.

The “New Medical Science” concept defines the future direction of medical development and guides the innovation of medical education. It aims to transform medicine from a “biomedical sciences based medicine” to one that integrates knowledge from other disciplines, such as Arts, Engineering, and Science. This approach seeks to cultivate high-level medical innovators who can adapt to the new generation of technological revolution and apply cross-disciplinary knowledge to solve the cutting-edge problems in the field of medicine [1]. Interdisciplinarity, a more comprehensive and deeper understanding of the value of life, and a holistic and systemic view are the key characteristics of the New Medical Science [2]. As such, even classical and traditional courses must undergo curricular innovations to align with the principles of New Medical Science, ensuring a student-centered approach to learning.

One critical priority in reforming traditional medical education is to identify leaning challenges students face and guide curriculum innovation through the lens of New Medical Science. The course must evolve to reflect the paradigm shift from a “disease-centered” to a “health-centered” model, while simultaneously fostering students’ systemic thinking through restructuring modular knowledge frameworks. This study aims to develop an innovative pedagogical approach tailored to cultivating medical professionals in the era of New Medical Science.

*Corresponding author: Wei Zhao, Center for Experimental Medical Science Education, Shanghai Jiao Tong University School of Medicine, Shanghai, 200025, China, E-mail: zhaowei_sjtu@sjtu.edu.cn

Chang Liu and Ping He, Department of Immunology and Microbiology, Shanghai Jiao Tong University School of Medicine, Shanghai, China. <https://orcid.org/0000-0002-9996-9756> (C. Liu)

Methods

Learning situation and curriculum analysis

A questionnaire survey was conducted among students of the five-year clinical medicine program to understand the current situation of their learning (Supplementary Material 1). The questionnaire comprises 15 questions pertaining to students' study habits during the course, the challenges they encounter in acquiring extensive knowledge, their capacity to apply their knowledge to address clinical problems, and their comprehension of infectious disease prevention and control, as well as their awareness of physicians' professional responsibilities. A total of 151 undergraduate clinical medicine students participated in the survey. The questionnaire was designed to identify students' problems in the learning process, thereby informing a series of targeted course innovations. The study protocol was approved by the Research Ethics Committee of

the Basic Medical Sciences, Shanghai Jiao Tong University (Supplementary Material 2).

Learning objective design

To solve the problems above, we designed the learning objectives of the curriculum based on the outcome-based education (OBE) concept [3, 4]. These objectives covered three aspects: professional knowledge, professional skills, and comprehensive attitudes (Table 1).

Reconstruction and expansion of teaching content

Construction of organ-system based knowledge system

In collaboration with clinical teachers, a set of 30 clinical cases covering common infectious pathogens was compiled (Table 2). These cases are from different organ systems, and

Table 1: Learning objectives of Medical Microbiology.

Type of objective	Learning objective
1. Professional knowledge	1.1 Characterize the biological characteristics of significant pathogenic microorganisms
	1.2 Outline the virulence factors of crucial pathogenic microorganisms, the illnesses they induce, and the fundamental principles for prevention and treatment
	1.3 Enumerate the laboratory diagnostic approaches for important pathogenic agents
	1.4 Elucidate and retell the key terminologies, commonly used phrases, and concepts within the field of Medical Microbiology
	1.5 Compile and present the prevalent pathogens in various systems of the human body
	1.6 Summarize the key events in the historical development of Medical Microbiology
	1.7 Comprehensively compare the similarities and differences in biological characteristics, pathogenic mechanisms, and prevention principles in emerging/re-emerging pathogens and other known pathogens
2. Professional skills	2.1 Present a summary of the basic research strategies and techniques used in Medical Microbiology
	2.2 Describe the aseptic procedures, isolation and culturing methods, as well as common disinfection and sterilization techniques used in diagnosis and treatment
	2.3 Formulate diagnostic plans for the identification of unidentified microbial infections
	2.4 Recognize the features of pathogens within the same system
	2.5 Design the research plan for unknown pathogens based on the characteristics of known pathogens
3. Comprehensive attitudes	3.1 Remember and describe the important and substantial contributions made by outstanding scientists to the progress and development of Medical Microbiology
	3.2 Elucidate the contributions that Chinese scientists have made to the development of Medical Microbiology
	3.3 Utilize an all-encompassing approach and engage in critical thinking processes in order to help foster a deeper understanding of the interrelationships among microorganisms
	3.4 Formulate a comprehensive strategy for the prevention and control of microbial infections by taking into account the One Health perspective
	3.5 Comprehend and analyze the connection between the development level of a country and its ability to control infectious diseases
	3.6 Summarize and highlight the pivotal and essential role that medical professionals assume in the process of controlling infectious diseases
	3.7 Recognize and gain a thorough understanding of the typical ethical dilemmas and issues that emerge within the context of Medical Microbiology during clinical practice scenarios

Table 2: Pathogens corresponding to different systems in the case-based learning cases.

Human system	Pathogens covered in the content
Respiratory system	<i>Streptococcus pneumoniae</i> , <i>Haemophilus influenzae</i> , <i>Mycoplasma pneumoniae</i> , <i>Mycobacterium tuberculosis</i> , influenza virus, and coronavirus
Digestive system	<i>Escherichia coli</i> , <i>Shigella</i> , <i>Salmonella</i> , <i>Helicobacter pylori</i> , <i>Clostridioides difficile</i> , rotavirus, and hepatitis B virus
Nervous system	<i>Neisseria meningitidis</i> , <i>Clostridium tetani</i> , <i>Clostridium botulinum</i> , poliovirus, rabies virus, epidemic type B encephalitis virus, and <i>Borrelia burgdorferi</i>
Urogenital system	<i>Neisseria gonorrhoeae</i> , <i>Treponema pallidum</i> , <i>Chlamydia trachomatis</i> , <i>Ureaplasma urealyticum</i> , <i>Candida albicans</i>
Hematologic system	EB virus, human immunodeficiency virus, and human T-lymphotropic virus
Mucocutaneous system	<i>Staphylococcus aureus</i> , human papillomavirus, varicella-zoster virus, and <i>Treponema pallidum</i>
Circulation system	Dengue virus, Hantavirus, and <i>Leptospira interrogans</i>

the teaching is carried out in the form of case-based learning (CBL). The CBL method was adopted to guide students in discussion and problem-solving, facilitating the cultivation of clinical systematic thinking.

Introduction of the One Health concept

Research on emerging and re-emerging pathogens has confirmed that many of them are transmitted from animals to humans, or that environmental changes have accelerated the transmission process. Consequently, students should adopt a macro-systemic perspective throughout their course of study, encompassing the harmonious unity of “human health-animal health-environmental health.” This underscores the significance of the One Health concept [5]. The course has established a case library of pathogens with One Health characteristics, encompassing critical pathogens such as *Yersinia pestis*, coronaviruses, Zika virus, avian influenza virus, etc. Through the utilization of case discussions and post-class reflections, students are guided to explore the significant relationship between the One Health concept and the transmission and prevalence of emerging pathogens.

Integration of disciplinary frontier knowledge based on critical thinking

The relationship between microorganisms and human health has both negative aspects, such as infectious diseases caused by pathogens, and beneficial aspects, when the microorganisms and human body are in a state of balance. For example, the study of the human microbiota has become a focus of medical research in recent years. Maintaining a balance of microbiota in the body plays a crucial role in promoting overall health [6]. Besides, some microorganisms may not only cause disease, but may also have protective effects under certain conditions or in certain diseases [7].

These advances at the frontiers of the discipline serve as suitable material for developing students’ critical thinking skills and should also be integrated into the teaching content.

Deep integration of professional education and holistic competency development

Guided by the educational principle of “fostering national identity with global vision, advancing scientific thinking, promoting research integrity, and enhancing professional excellence,” this initiative deeply explored pedagogical elements through multi-faceted approaches. A curated collection of 26 landmark disciplinary developments was compiled and supplemented with micro-lectures, while open-ended critical thinking questions were strategically designed to seamlessly integrate competency cultivation components into the curriculum (Table 3). This organic fusion transformed theoretical knowledge into professional practice, creating a cohesive learning experience that simultaneously strengthened disciplinary mastery and cultivates core competencies.

Innovation of teaching model

A “4C” (stands for combination of lecturing and discussion, combination of online and offline learning, combination of professional knowledge and competency cultivation, and combination of basic and frontier knowledge) teaching model was developed (Figure 1). In order to scientifically evaluate the students’ ability of problem solving, a class of 30 students was selected for the teaching model innovation (Class A, containing 17 female students and 13 male students), and another class of 30 students taught with traditional teaching model was used as a control (Class B, containing 18 female students and 12 male students). The two parallel classes maintained identical teaching parameters

Table 3: Reading materials for Medical Microbiology.

Title of reading material	Professional entry point	Contents of the materials	Corresponding learning objectives (Table 1)	Reference
History of the development of Medical Microbiology	The development history of Medical Microbiology	A retrospective analysis of significant infectious diseases in historical contexts	1.6, 3.1, 3.2	–
The relationship between human microbiota and health	Human microbiota	The dialectics regarding the problem of the human body's normal flora	1.4, 3.2, 3.3	[8]
The threat of nosocomial infection	Nosocomial infection	A review in a retrospective manner of the cases involving nosocomial infections	1.2, 2.2, 3.6	–
Christmas rescue	Artificial passive immunity – antiserum	Emil Adolf von Behring, the recipient of the first Nobel Prize in Physiology or Medicine, applied antiserum to treat diphtheria	1.2, 1.5, 1.6	[9]
The threat of biosafety events	Biosafety and bioterrorism	A retrospective analysis of bioterrorism events across the globe	1.2, 3.4, 3.5, 3.7	[10, 11]
The discovery of penicillin	Development of antibiotics	The historical journey of penicillin's discovery	1.2, 2.1, 3.1, 3.3	[12]
The discovery of <i>Staphylococcus aureus</i>	Pathogenesis of <i>Staphylococcus aureus</i>	History of the discovery of <i>Staphylococcus aureus</i>	1.2, 1.5, 1.6, 3.6	[13]
Exposing the two-sided character of gut microorganisms	Pathogenesis of <i>Escherichia coli</i>	A dialectical look at <i>Escherichia coli</i>	1.2, 1.5, 1.6, 2.3, 3.1, 3.6	[14]
Typhoid Mary	Carriers of <i>Salmonella</i> Typhi	Discovery of the first carrier: Typhoid Mary	1.2, 1.4, 1.5, 2.4, 3.3	[15]
The Nobel Prize hidden in the gastrointestinal tract	Biological properties and pathogenesis of <i>Helicobacter pylori</i>	The 2005 Nobel Prize in Physiology or Medicine: <i>Helicobacter pylori</i> discovery	1.1, 1.2, 1.5, 1.6, 2.1, 2.3, 3.1	[16]
Friend or foe? <i>Helicobacter pylori</i>	Biological properties and pathogenesis of <i>Helicobacter pylori</i>	Relationship between <i>Helicobacter pylori</i> and human health	2.5, 3.3, 3.7	[7]
From Huanglong decoction to Fecal microbiota transplantation	Treatment of <i>Clostridioides difficile</i> infection	Development of Fecal microbiota transplantation	1.2, 1.4, 1.5, 2.1, 2.5, 3.3, 3.7	[17]
Koch's Nobel Prize	Discovery of <i>Mycobacterium tuberculosis</i>	The discovery of <i>Mycobacterium tuberculosis</i> by Koch	1.2, 1.5, 1.6, 2.2, 3.1	[18]
Spring fills the world	Treatment of <i>Pseudomonas aeruginosa</i>	The first case of phage therapy for drug-resistant bacterial infection in China	1.2, 1.5, 2.1, 2.4, 3.1, 3.2, 3.3, 3.6, 3.7	[19]
From “the Scourge of God” to “a National Scholar”	Infection of <i>Yersinia pestis</i>	Pandemic of plague in the history; Wu Liande's prevention and control of plague in the North-east China	1.2, 1.6, 2.1, 3.1, 3.2, 3.4, 3.5, 3.6	[20]
Revealing the secrets of Rickettsia	Cultivation of Rickettsiae	The story of Wei Xi and Xie Shaowen's research on Rickettsiae	1.2, 1.4, 1.5, 2.1, 3.2, 3.4, 3.5, 3.6	–
The emissary of bright	Pathogenesis of <i>Chlamydia trachomatis</i>	Tang Feifan's Discovery of <i>Chlamydia trachomatis</i>	1.1, 1.2, 1.3, 1.5, 2.1, 2.3, 3.2, 3.6, 3.7	[21]

Table 3: (continued)

Title of reading material	Professional entry point	Contents of the materials	Corresponding learning objectives (Table 1)	Reference
The threat of emerging and re-emerging infectious diseases	Viral infections	Epidemics of emerging and re-emerging infectious diseases	1.2, 1.4, 1.5, 2.4, 3.3, 3.4, 3.5	[22]
The shape-shifting demon	Influenza virus	The history of the flu epidemic	1.2, 1.4, 1.5, 1.6, 2.4, 3.4, 3.5, 3.6	[23]
The evil of the coronet	Coronavirus	The prevention and control of Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome (MERS) and Coronavirus Disease 2019 (COVID-19)	1.2, 1.4, 1.5, 1.6, 2.4, 2.5, 3.4, 3.5, 3.6	[22]
The transformation of the sugar pill	Poliovirus	The history of the invention of polio vaccine, including the stories of Salk, Sabin and Gu Fangzhou	1.2, 1.4, 3.2, 3.5, 3.6	[24]
The battle against Hepatitis B	Hepatitis B virus	The major achievements of hepatitis B prevention and control in China	1.2, 1.4, 1.5, 1.6, 2.4, 3.2, 3.5, 3.6	[25]
Slowing the pace of the invisible demon	Human immunodeficiency virus	HIV prevention and control achievements	1.2, 1.4, 1.6, 2.1, 2.3, 3.1, 3.4, 3.5, 3.6, 3.7	[26]
Its fame spreads across the world	Ebola virus	Chinese medical teams aiding Africa in the fight against Ebola	1.2, 1.6, 3.4, 3.5, 3.6	[27]
Outstanding talents aid the masses	Human papillomavirus (HPV)	The invention of HPV vaccine	1.2, 1.4, 3.3	–
Discovery of fungal mini-culture	Biological features of fungi	The invention of small culture of fungi	1.1, 1.3, 1.4, 2.3, 3.2	[28]

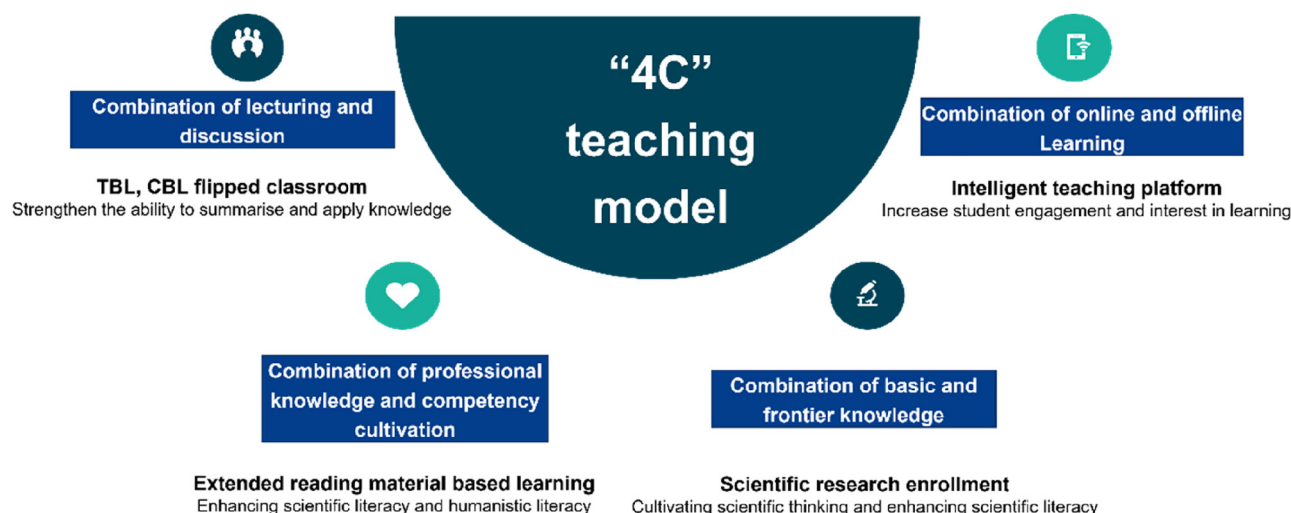


Figure 1: The “4C” teaching model. TBL, team-based learning; CBL, case-based learning.

(40 class hours, same textbook and instructor) throughout the synchronized implementation.

Combination of lecturing and discussion

Teaching activities were designed under the guidance of a student-centered philosophy. By setting pre-class questions, conducting in-class interactive discussions through team-based learning (TBL) and flipped classrooms, and assigning after-class assignment questions, students' systematic thinking and ability to utilize knowledge were targeted. CBL learning is aligned to the learning objectives of each section of content, creating problem situations and guiding students to solve the problem through discussion. The One Health case library provides a review of typical One Health cases in infectious diseases. It also includes a simulation of an outbreak of an infectious disease with an unknown etiology, which facilitates a discussion on designing effective solutions.

Combination of professional knowledge and competency cultivation

Relying on the extended reading materials and micro-courses, competency cultivation was carried out. Through pre-class self-study, in-class sharing, and after-class practice, a sense of importance and responsibility among students with regard to the prevention of infectious diseases was constructed. In detail, prior to class, students were expected to read the reading materials, understand the background of the story, conduct independent learning and reflection on the fundamental professional issues involved in the material story and the open-ended questions designed for the story. During class, students were expected to discuss and exchange views on these issues, and to carry out content-related practices such as writing scientific articles, producing scientific posts, and participating in scientific research practices.

Combination of basic and frontier knowledge

Teachers integrated the frontier of the discipline into the teaching content, stimulated students' interest in scientific research through lectures, discussions, post-course open assignments, and other teaching activities, and encouraged students to carry out scientific research and innovation. Students with willingness to explore will be led and instructed to aim at the scientific problems embedded in this course through guided reading of the literature, research strategy designing, and active participation. Students with excellent

projects were recommended to participate in innovation competitions, and they were coached to write and publish scientific papers based on original research results.

Combination of online and offline learning

Teachers made use of high-quality online resources during "pre-class–in-class–after-class." The design of the four teaching sessions "online pre-testing–offline participation–online expansion–offline practice" was carried out throughout the whole teaching process, extending both the time and space of traditional learning.

Curriculum evaluation

The evaluation process, characteristic of multi-means, multi-subject, multi-dimensional teaching evaluation, was designed around the degree of achievement of teaching objectives, including process evaluation and summative evaluation (Table 4), extending from the single dimension of theoretical knowledge to multiple dimensions, including humanistic literacy, scientific thinking, professional competence, and professional responsibility. The evaluation process involved three major parts: (1) A massive open online course (MOOC) unit quiz was set up before class to test the online learning effect of students, according to which the teachers would adjust the teaching content; (2) Student-student mutual evaluation was organized in combination with teacher evaluation to promote the internalization of knowledge through cross-feedback; (3) By adopting an inclusive learner-centered approach, tiered assignments were implemented to allow students to self-select appropriate challenge levels, facilitating progressive knowledge acquisition from foundational to advanced concepts. This scaffolded learning design promoted cognitive restructuring through iterative reinforcement. For assessment, instructors provided tailored feedback, offering personalized guidance where feasible and standardized responses when necessary to ensure equitable engagement across all learner cohorts. Based on the evaluation results, one-on-one learning guidance was provided to students with learning difficulties; for students with higher learning needs, scientific research practices were recommended to help with knowledge transformation. At the end of the course, excellent assignments were displayed online to promote learning and excellence. The overall evaluation was based on the spiral of "evaluation-feedback-improvement-enhancement." Both Class A and Class B took the final examination, unpaired Student's *t*-test was used to compare the results of the two classes. All the students completed self-assessment

Table 4: Curriculum evaluation.

Part	Aspects of evaluation	Proportion in overall evaluation/effects	Evaluation indicators
Online learning	Massive open online course (MOOC) learning	10 %	Fully completed or not
	Online interactions	5 %	Number of participations, accuracy of questions answered
	Online unit tests	5 %	Correctness rate
In-class learning	Classroom test	10 %	Correctness rate
	In-class presentation	25 % (15 % teacher evaluation + 10 % student evaluation)	Presentation preparation, presentation content, presentation effect, co-operation and communication, adaptability, etc.
	Final examination	25 %	Correctness rate
Extended learning	Assignments/open questions	15 %	Various forms of presentation, substantial content, academic norms, and reflection of scientific thinking
	Extended reading	5 %	Science ethics and professionalism
Additional evaluation	Micro-lecture design	Certificate	Design and practice of micro-lecture
	Self-assessment questionnaire	Teaching improvement	The impact of teaching on students' attitude

questionnaires regarding their awareness of infectious disease prevention and control, as well as professional responsibility establishment (Supplementary Material 3).

Results

Learning status of students in Medical Microbiology

Through an in-depth analysis of the teaching content characteristics, three major problems in curriculum learning were identified (Table 5): knowledge confusion and difficulty in application, weak systematic and critical thinking, and insufficient understanding in disease prevention and professional responsibility.

Improvements in students' academic performance and abilities

All students in classes A and B took the final examination. After the innovation, students' academic performance improved significantly. They performed better in questions that required flexible knowledge application, such as A2 – type questions and case – analysis questions. The

differences in scores for application – based questions were statistically significant (Table 6).

Students also actively participated in scientific research projects. A total of 10 groups of students took part in college students' innovation projects or research-based learning (RBL) projects in 2021–2023. They published over six research papers and won six innovation-related competition awards, including four national-level awards (Supplementary Material 4).

Enhancement of students' scientific thinking

When students from Class A chose topics for presentation in class, many of them chose the theme of systematic understanding of microorganisms, such as summarizing pathogens according to different systems, emphasizing microbiota balance in microbial therapy, as well as human-animal-environmental macro-systems thinking on pathogen prevention and control in relation to the concept of One Health. They also designed seven high-quality maps regarding common pathogens in different systems, indicating the internalization of systematic thinking. For students from Class B, since the “4C” teaching model implemented in Class A was not adopted, comparable evaluation methods and equivalent outcome measures were not available.

Table 5: Learning status of students in Medical Microbiology.

Questionnaire content	Students' feedback	Percentage of students
Learning habits	Mainly rely on the lectures and the textbooks to learn	81 % (122/151)
Knowledge acquisition	Tend to confuse different knowledge points when learning	94 % (142/151)
Ability to apply knowledge	Having difficulty in applying knowledge to diagnosis in case-based learning discussions	86 % (130/151)
	Inability to identify the pathogen when confronted with an unknown infectious disease was a significant challenge	95 % (144/151)
The level of understanding of scientific concepts	Gained solid understanding of the One Health concept and a clear recognition of its importance	11 % (17/151)
	Developed the ability to understand the relationship between microorganisms and their hosts in a dialectical manner	27 % (41/151)
Attitude towards the prevention and control of infectious diseases	Will actively think about how to apply what they learned in the course in future clinical work	26 % (40/151)
	Considering that raising awareness of infectious disease prevention is an important professional quality for doctors	37 % (57/151)

Table 6: Comparison of final examination results (score, mean $\pm$ S.E.).

Question type	Characteristics of the questions	Class A (n = 30)	Class B (n = 30)	t-Value	p-Value
MCQ-A1	Examines basic knowledge of the course, with relatively simple questions	23.57 $\pm$ 1.99	23.17 $\pm$ 2.23	0.73	0.4670
MCQ-A2	Relevant to the clinical cases, testing clinical application skills	20.83 $\pm$ 2.45	18.50 $\pm$ 2.34	3.76	0.0004
Short answer questions	Examines basic concepts	21.48 $\pm$ 1.85	21.73 $\pm$ 2.07	0.49	0.6230
Case study questions	Diagnosis of clinical cases, examination of pathogenesis, prevention and treatment of the pathogens	20.03 $\pm$ 1.51	16.18 $\pm$ 1.67	9.83	<0.0001
Total		85.92 $\pm$ 1.51	79.58 $\pm$ 4.38	5.96	<0.0001

MCQ, multiple choice question.

Improvement in students' disease prevention awareness and professional qualities

Analysis of the questionnaire (Supplementary Material 2) data revealed significant intergroup differences in learning outcomes. Class A demonstrated marked improvements across all assessed domains: (1) 100 % students achieved advanced comprehension of preventive medicine principles, recognizing both the clinical priority of prevention over treatment and its socioeconomic implications for national development; (2) all participants exhibited enhanced awareness of healthcare professionals' responsibilities in infection control ($p < 0.01$ vs. baseline); (3) 33.3 % (10/30) students voluntarily engaged in microbiology

research training, demonstrating knowledge application. Comparatively, Class B showed modest gains: while 80 % developed professional competency awareness regarding infection prevention and participated in related practices, only 10 % (3/30) pursued supplementary research training in microbiology.

Students' evaluation of the curriculum

The course received overwhelmingly positive evaluations from students, achieving a top 3 % ranking among all college courses for teaching effectiveness. Satisfaction rates reached 100 % (30/30) in Class A and 86.7 % (26/30) in Class B, with students particularly praising the development of essential microbiological reasoning skills and clinically relevant microbiological literacy. All Class A students

(100 %, 30/30) reported acquisition of foundational microbiological reasoning skills and clinically applicable microbiological literacy, compared to 83.3 % (25/30) of Class B students.

Discussion

Guided by the OBE concept, the course learning objectives were designed to encompass core knowledge in Medical Microbiology, microbiological thinking skills, a sense of responsibility for infectious disease prevention and control, as well as an understanding of and adherence to scientific ethics and norms [4].

Updating teaching content must be centered on the development of students and in line with the development of the subject and cutting-edge teaching concepts. The teaching content of Medical Microbiology encompasses over 140 different types of microorganisms, which is a great challenge for students [29]. Based on the pre-class survey, the students felt easily confused during the learning process. Concurrently, it is evident that students were not yet equipped with the necessary skills to utilize their existing subject knowledge to recognize emerging pathogens. Furthermore, the current knowledge framework in this course remains predominantly rooted in biological taxonomy, which inadequately develops students' capacity for organ-system integration when analyzing microbial pathogenesis. This taxonomic approach creates a significant pedagogical gap, limiting learners' ability to conceptualize microorganisms within clinically-relevant systemic contexts. The current curriculum fails to adequately cultivate two essential competencies: (1) macro-level systemic thinking through application of the One Health paradigm, and (2) critical analysis skills for evaluating emerging infectious diseases and contemporary challenges in microbiological sciences. More critically, students demonstrate insufficient awareness that infectious disease prevention constitutes not merely academic knowledge, but rather a fundamental professional competency and clinical obligation integral to modern medical practice. Cultivating these professional competencies requires students to: (1) internalize fundamental microbiological knowledge and practical skills, (2) standardize evidence-based clinical behaviors in diagnosis and treatment, and (3) effectively translate theoretical knowledge into clinical decision-making and practice. These competencies are seldom encountered by students in prerequisite courses and are also comparatively lacking. Therefore, in summary, the teaching innovations in this course have been updated accordingly in terms of the teaching contents.

The "4C" teaching model effectively addressed the existing teaching problems. The combination of lecturing and discussion provided students with more opportunities to think and communicate, enhancing their understanding and application of knowledge. The integration of professional knowledge and competency cultivation not only improved students' professional skills but also cultivated their values and sense of responsibility. The combination of basic and frontier knowledge inspired students' innovation, and the online-offline combination optimized the learning process.

The diversified evaluation system, with its emphasis on multiple dimensions and formative evaluation, provided a comprehensive assessment of students' learning. It not only evaluated students' knowledge acquisition but also their thinking abilities, professional qualities, and holistic competency. This helped teachers adjust teaching strategies in a timely manner and promoted students' self-improvement.

The analysis of final examination scores revealed that while both Class A (reform-based teaching) and Class B (traditional teaching) showed comparable performance on basic knowledge recall (A1-type and short-answer questions), Class A demonstrated significantly better outcomes in clinical application tasks (A2-type questions and case analyses). This suggests that although both instructional approaches effectively support foundational knowledge retention, the reformed teaching method appears more conducive to developing higher-order competencies such as clinical reasoning and knowledge application.

The success of this curriculum innovation in Medical Microbiology offered valuable lessons for medical education reform. It emphasized the importance of aligning teaching with the requirements in the era of New Medical Science, focusing on cultivating students' comprehensive abilities, and integrating multiple teaching methods and evaluation means. Future medical education should continue to strengthen interdisciplinary integration, incorporate digital technology, and promote the sharing of innovative teaching experiences.

However, this study has notable limitations. The teaching reform was only implemented and evaluated in two 30-student classes, resulting in a relatively small sample size. Future studies should validate these findings in larger class settings.

In conclusion, this study demonstrated that the innovative reform of Medical Microbiology curriculum under the "New Medical Science" paradigm had yielded significant educational outcomes. The restructured course not only enhanced students' academic performance and core competencies but also established a replicable framework

for contemporary medical education transformation. While these achievements are noteworthy, ongoing refinement of both pedagogical approaches and curricular content remain essential to maintain alignment with the dynamic landscape of medical education and healthcare advancement.

Acknowledgments: I would like to acknowledge Xiaoyin Niu for revising the article and my colleagues Jinhong Qin, Wei Zhao, Jing Tao and Yufeng Yao from the medical microbiology teaching group.

Research ethics: Not applicable.

Informed consent: Not applicable.

Author contributions: Chang Liu designed and implemented the teaching design, Ping He provided assistance in teaching process, Yundong Sun and Hong Lu provided teaching resources such as photographs, Zhuoyang Zhang assisted in making online teaching resources, and Ke Dong was involved in writing and revising the manuscript. The authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Use of Large Language Models, AI and Machine Learning Tools: None declared.

Conflict of interest: The authors state no conflict of interest.

Research funding: This work was supported by Medical Education Research Project of Medical Education Branch of Chinese Medical Association (2018B-N03011, 2023B344).

Data availability: Not applicable.

References

- Jerjes W. Cross-disciplinary insights for overcoming speak-up barriers in medical education. *J Patient Saf* 2025;21:e1–2.
- Han LF, Wang Z, Zhou XN, Guo XK. Embarking on the era in new medicine: reshaping the systems of medical education and knowledge. *Glob Med Educ* 2024;1:3–12.
- Thomas YS. A historical study of the contributions of Dr. William G. Spady to education reform. Providence, RI: Johnson & Wales University; 2013.
- Yang P. Humanities education reform exploration and practice under outcomes-based education (OBE). *Obraz Nauka Educ Sci* 2020;22:77–96.
- Mettenleiter TC, Markotter W, Charron DF, Adisasmito WB, Almuhairei S, Behravesh CB, et al. The one health high-level expert panel (OHHLEP). *One Health Outlook* 2023;5:18.
- Dominguez-Bello MG, Godoy-Vitorino F, Knight R, Blaser MJ. Role of the microbiome in human development. *Gut* 2019;68:1108–14.
- Gravina AG, Zagari RM, Musis CD, Romano L, Loguercio C, Romano M. *Helicobacter pylori* and extragastric diseases: a review. *World J Gastroenterol* 2018;24:3204–21.
- Yu Z. Historical review: dialectic of normal human flora (Chineses). *Chin J Microecol* 2001;13:3–4.
- Raju TN. The Nobel chronicles. 1901: Emil Adolf von Behring (1854–1917). *Lancet* 1998;352:75.
- Bower WA, Yu Y, Person MK, Parker CM, Kennedy JL, Sue D, et al. CDC guidelines for the prevention and treatment of anthrax, 2023. *MMWR Recomm Rep* 2023;72:1–47.
- Butler T. Plague gives surprises in the second decade of the twenty-first century. *Am J Trop Med Hyg* 2023;109:985–8.
- Kardos N, Demain AL. Penicillin: the medicine with the greatest impact on therapeutic outcomes. *Appl Microbiol Biotechnol* 2011;92:677–87.
- Newsom SW. Ogston's coccus. *J Hosp Infect* 2008;70:369–72.
- Gozzi IC, Rosa BG, Medeiros I, Silva BD, Rodrigues GM, Yoshihara FA, et al. The adoption of a superhero bacteria: *Escherichia coli* and its adventures in microbiology education. *FEMS Microbiol Lett* 2025;372:fnaf042.
- Marineli F, Tsoucalas G, Karamanou M, Androutsos G, Mary Mallon (1869–1938) and the history of typhoid fever. *Ann Gastroenterol* 2013;26:132–4.
- Lazarate C, Quigley EM. A history of the discovery of *Helicobacter Pylori*, with special reference to Giulio Bizzozero. *J Gastrointest Liver Dis* 2024;33:535–41.
- Lee PC, Chang TE, Wang YP, Lee KC, Lin YT, Chiou JJ, et al. Alteration of gut microbial composition associated with the therapeutic efficacy of fecal microbiota transplantation in *Clostridium difficile* infection. *J Formos Med Assoc* 2022;121:1636–46.
- Ligon BL. Robert Koch: Nobel laureate and controversial figure in tuberculin research. *Semin Pediatr Infect Dis* 2002;13:289–99.
- Turner PE, Azeredo J, Buurman ET, Green S, Haaber JK, Haggstrom D, et al. Addressing the research and development gaps in modern phage therapy. *Phage (New Rochelle)* 2024;5:30–9.
- Lien T, Tuck W. Investigations into the relationship of the Tarbagan (Mongolian marmot) to plague. *Lancet* 1913;182:529–35.
- Tang FF, Huang YT, Chang HL, Wong KC. Further studies on the isolation of the trachoma virus. *Acta Virol* 1958;2:164–70.
- Docea AO, Tsatsakis A, Albulescu D, Cristea O, Zlatian O, Vinceti M, et al. A new threat from an old enemy: re-emergence of coronavirus (Review). *Int J Mol Med* 2020;45:1631–43.
- Krammer F, Hermann E, Rasmussen AL. Highly pathogenic avian influenza H5N1: history, current situation, and outlook. *J Virol* 2025;99:e0220924.
- Sahu H, Choudhary SG, Gaidhane A, Chakole S, Jonas Salk (1914–1995): pioneering the fight against polio and beyond. *Cureus* 2024;16:e69681.
- Xie L, Liu G, Liu Y, Li P, Guo H. Prevalence of low-level viremia in the treatment of chronic hepatitis B in China: a systematic review and meta-analysis. *BMJ Open* 2025;15:e088756.
- Ho DD. Time to hit HIV, early and hard. *N Engl J Med* 1995;333:450–1.
- Orievulu K, Hinga A, Nkosi B, Ngwenya N, Seeley J, Akanlu A, et al. A scoping review of ethics review processes during public health emergencies in Africa. *BMC Med Ethics* 2024;25:63.
- Zhou J, Sun XY, Stenzel DJ, Frazer IH. Expression of vaccinia recombinant HPV 16 L1 and L2 ORF proteins in epithelial cells is sufficient for assembly of HPV virion-like particles. *Virology* 1991;185:251–7.
- Patrick R, Murray KS, Michael AP. Medical microbiology. Amsterdam, Netherlands: Elsevier; 2021.

Supplementary Material: This article contains supplementary material (<https://doi.org/10.1515/gme-2025-0018>).