

Comprehensive education reform in a basic medical science course in Nanjing, China

Feifei Zou¹, Xixi Li¹, and Yang Xu²

¹MD, Lecturer, School of Medicine, Nanjing University of Chinese Medicine, Nanjing, China

²MMed, Teaching Assistant (Experiment Teaching Post), School of Medicine, Nanjing University of Chinese Medicine, Nanjing, China

Abstract

The undergraduate medical curriculum faces challenges such as a disconnect between theory and clinical practice, a lack of practical opportunities, and a single approach to teaching. Guided by the principles of competency-based education and constructivist teaching, we studied the impact of comprehensive educational reform measures to connect foundational knowledge with clinical application, public health relevance, and foster student engagement using a medical parasitology course as a model. All 78 students in the 2023 cohort received the comprehensive teaching reform program, while the 80 students in the 2022 cohort received traditional lecture-based teaching. Course content was regularly updated to align with global, national, societal, and learner needs. Multiple active teaching strategies were implemented: role-play of parasite life cycles and case-based learning (CBL), regular online structured questionnaires, and student production of science communication videos. Additionally, personalized learning pathways and a multidimensional evaluation framework were introduced to accommodate diverse learner profiles and monitor competency progression. Outcomes were

evaluated across three dimensions: academic performance, teaching outcomes, and student satisfaction and feedback. Learners in the experimental cohort performed better on their final examination scores than historical control group. Evaluation through five targeted questionnaires covering the main reforms revealed that over 77.95% of students agreed that the reform was effective. Students created six science public education videos, designed seven different public health surveys, and collected 800 valid responses. This reform suggested that medical parasitology teaching was strengthened when foundational knowledge was linked to clinical, public-health, and participatory learning contexts. Consistent with principles of competency-based education and constructivist principles, future refinement may focus on involving clinical physicians in case-based teaching, integrating online and offline teaching to provide data-driven personalized guidance, and strengthening scaffolding for collaborative and individualized learning.

Keywords: CBE, constructivist learning theory, clinical practical competence, medical parasitology

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Email: Feifei Zou (feifeizou2@163.com)

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Background

Medical parasitology remains one of the core courses in the field of medicine. As an important bridge connecting basic medicine, clinical medicine and preventive medicine, this course provides a solid foundation for medical students to delve deeper into the study of infectious diseases, diagnosis, prevention and treatment in clinical medicine. However, its educational landscape faces profound challenges globally. Clinically, these conditions carry high rates of misdiagnosis and underdiagnosis.¹ Therefore, clinicians should enhance their understanding of parasitic diseases, which are “preventable and treatable”. Currently, curriculum teaching faces the following difficulties and challenges:

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- 1) course content updates lag significantly, failing to align with global, national, and regional development priorities or address core student needs; 2) the teaching methods were monotonous, the knowledge points were easily confused; 3) theory and practice were disconnected, and students' interest in learning was not high; 4) significant variance existed in student learning progression, with insufficient mechanisms for personalized academic support; and 5) the assessment and evaluation system overly relied on final exam results, which failed to fully motivate students' initiative.

Confronting these challenges requires systematic reforms in course content, curriculum design and

pedagogical approaches, which would be underpinned by principles of competency-based medical education (CBE) and constructivist learning theory in our study. The constructivist learning theory, whose philosophical origins are frequently ascribed to Kant and whose educational origins to Piaget, is based on the premise that the act of learning is based on a process which connects new knowledge to pre-existing knowledge.^{2,3} The principles of constructivism align closely with addressing the challenges mentioned above in teaching medical parasitology, because they emphasize designing teaching scenarios that facilitate students' deep engagement, and implementing diverse and multi-dimensional teaching activities.

Competency-based education (CBE) is an approach to preparing physicians for practice that is fundamentally oriented to graduate outcome abilities and organized around competencies derived from an analysis of societal and patient needs. It deemphasizes time-based training and promises greater accountability, flexibility, and learner-centeredness.⁴⁻⁶ The rationale behind CBE emphasizes learner-centeredness and social relevance, directly addressing the key teaching challenges we encountered, particularly challenges 1, 3, and 4 outlined above.

This study was driven by principles of CBE, with constructivist learning theory guiding instructional design and implementation. The reform aimed to develop students' proficiency in fundamental theories, diagnostic techniques, and prevention strategies of human parasitology, while enhancing practical, analytical, and digital literacy skills applicable to clinical and public health practice. It also fostered higher-order thinking (analysis, evaluation, innovation), encouraged exploration of emerging topics in parasitology, and strengthened professional commitment, social responsibility, and public health awareness.

Methods

This study was conducted at the School of Medicine, Nanjing University of Chinese Medicine, within the undergraduate clinical medicine program, focusing on the compulsory medical parasitology course for second-year students (36 class hours, 2 credits). All students from two intact classes in each cohort were included in this study. Specifically, two classes from the 2023 cohort (n = 78) were assigned to the intervention group, while two classes from the 2022 cohort (n = 80) served as the control group. Inclusion criterion was full-time enrollment, and exclusion criteria included leave, transfer, withdrawal, or incomplete assessments. Three experienced parasitology instructors delivered the course, guided discussions and interactive exercises, and

provided feedback on student projects and collaborative activities. The teaching environment included lecture halls with multimedia projection, laboratory facilities for practical exercises, and the Rain Classroom online platform (a widely used mobile learning platform that integrates teachers and students via smart devices, enhances learning before, during, and after class)^{7,8} for quizzes, case submissions, a case bank, and supplementary resources beyond the course textbook. Ethical approval was obtained from the university's Institutional Review Board.

Prior to implementation, a pre-course open-ended survey was used as a formative needs-assessment tool (as a rapid, formative descriptive tool rather than a formal thematic analysis). Word-cloud visualization identified clinical, practice, case, analysis, and enrichment as the most frequent learner priorities (Figure 1). These findings guided the subsequent curriculum reform, including the expansion of case-based learning, practice-oriented projects, guided analytical tasks, and the enrichment of course content and diversification of teaching approaches. Five key teaching reforms were implemented (Table 1).

1. Continuous update of course content and flipped-classroom sessions

Course content was continuously revised using WHO and China CDC epidemiological data and recent parasitology research. Teaching content was updated to reduce focus on low-incidence parasitic diseases, while emphasizing increasing infections and emerging diseases. Trending public health topics, headlines, and real-time online discussions on parasitic infections were incorporated to enhance relevance and student engagement. Topics related to specific parasites were further explored in class through teacher-guided discussions that encouraged students to critically evaluate their scientific basis, factual accuracy, and ethical dimensions.

Two classes were reserved for flexible adjustment of the course content based on changes in global and national public health situations, as well as student feedback, through joint discussions between teachers and students. Students uploaded related materials and supplementary learning resources to the Rain Classroom online platform for access by instructors and peers. Students presented their findings and led discussion of critical analysis. After class, each group produced a summary report consolidating their findings and reflections, reinforcing knowledge integration and promoting self-directed learning.

Assessment: Application-oriented final-exam questions,

Figure 1: A word cloud regarding students' pre-course needs and interests

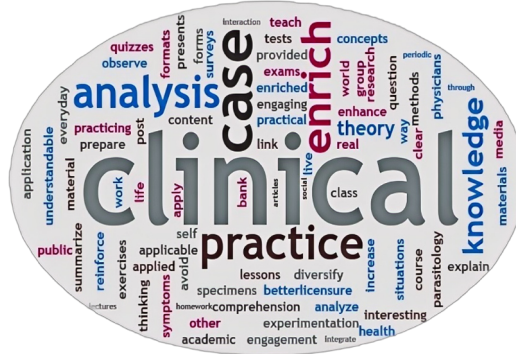


Table 1: Alignment of key teaching reforms, learning objectives, and assessment methods

Teaching reform components	Learning objectives	Assessment methods
<ul style="list-style-type: none"> Regular update of course content and two class sessions dedicated to flipped-classroom learning 	<ul style="list-style-type: none"> Enhance students' recognition of epidemiologically relevant parasitic diseases Strengthen clinical reasoning and application skills in diagnosis, treatment and prevention Critically access and use digital health information, increase engagement through real-world relevance 	<ul style="list-style-type: none"> Application-oriented questions in final examination Flipped-classroom discussion performance, peer group evaluations and instructor feedback Formative quizzes and real-time feedback via Rain Classroom
<ul style="list-style-type: none"> Role-play simulation of parasite life cycles 	<ul style="list-style-type: none"> Differentiate key parasite life-cycle features, enhance students' ability to analyze and explain parasite life cycles Cultivate students' scientific communication and collaborative problem-solving skills 	<ul style="list-style-type: none"> Life-cycle interpretation items in final examination Role-play performance, peer group evaluations and instructor feedback Formative quizzes
<ul style="list-style-type: none"> Case-based learning supported by a clinical case database 	<ul style="list-style-type: none"> Apply clinical reasoning in parasitic disease diagnosis and management, integrate epidemiological, laboratory, and clinical information Foster scientific communication and evidence-based decision-making skills Foster academic interaction and communication to support independent learning. 	<ul style="list-style-type: none"> Case-based questions in final examination Formative quizzes Course questionnaires and interviews, case discussion assessment with continuous feedback Quality of case analyses submitted to the database via Rain Classroom
<ul style="list-style-type: none"> Real-world application and science popularization projects (questionnaires, videos) 	<ul style="list-style-type: none"> Apply parasitology knowledge to real-life scenarios Develop students' ability to design and implement science-popularization projects Enhance students' digital media literacy and practical ability Cultivate students' science-communication skills and teamwork 	<ul style="list-style-type: none"> Quality of project outputs (questionnaires, videos) Formative feedback through peer evaluations, instructor reviews Feedback on social media platforms
<ul style="list-style-type: none"> Personalized learning via online platform 	<ul style="list-style-type: none"> Consolidate foundational and advanced knowledge Fostering an interest in scientific exploration, develop self-directed learning skills Enhance students' digital literacy 	<ul style="list-style-type: none"> Engagement with staged learning resources Formative feedback on discussions Performance in formative quizzes and simulations Overall final examination performance

in-class discussion performance, peer-group evaluations, and real-time feedback via Rain Classroom.

2. Role-play simulation of parasite life cycles

To clarify complex parasite life cycles (key course concepts), students engaged in a “parasite poker” role-play activity. The process was as follows: a) the teacher prepared “parasite poker”, and carefully selected six representative parasites with particularly complex life cycles (including *Toxoplasma gondii*, *Plasmodium vivax*, *Paragonimus westermani*, *Taenia solium*, hookworm and mosquito); b) students in each group selected the type of parasite to simulate by drawing lots; c) students take on the roles of “parasite”, “final host”, “intermediate host”, “vector”, “external environment”, respectively, and dynamically demonstrated the parasite’s transmission and survival process; d) the teacher and students collaboratively evaluated the role-play, and outstanding students were rewarded with the pokers.

Assessment: Life-cycle interpretation questions in formative quizzes and final exams, peer evaluations, instructor feedback.

3. Case-based learning (CBL) supported by a clinical database

Case-based learning (CBL) is an approach that involves linking clinical cases in healthcare-related fields to the relevant body of knowledge, with the goal of improving clinical performance, attitudes, and teamwork.^{9,10} Six clinical cases aligned with the curriculum (malaria, clonorchiasis, schistosomiasis, cysticercosis, hydatidosis, hookworm) were selected from de-identified archives.

Pre-class: Students reviewed textbook content and then completed a baseline quiz before accessing case materials and supplemental resources (patient history, labs, environmental context, and foundational parasite knowledge) on the Rain Classroom platform. In groups of 4–5, they analyzed key case aspects (diagnostic criteria) and shared preliminary insights on an online discussion board. Teachers prepared key task cards in advance to guide core learning objectives, covering life-cycle comprehension, clinical diagnosis, and management recommendations.

In-class: Following instructor-led lectures on key foundational concepts, groups of 4–5 analyzed assigned case components using the task cards, discussed differential diagnoses, treatment options, and preventive strategies, and presented their conclusions. Instructors facilitated discussion, prompted critical thinking, and

provided corrective feedback, while peers offered additional insights, promoting collaborative learning and deeper understanding of clinical reasoning.

Post-class: students uploaded their analyses and reflections to case-specific discussion boards on the Rain Classroom platform. Online quizzes and assessments were used to test students’ understanding of the key concepts covered in the class and to ensure that they could apply their learning to new scenarios. A parasitic disease database was connected to the learning platform, enabling students to upload case analyses and reflections.

Assessment: Case-based questions in formative quizzes and final exams, continuous in-class feedback and quality of submissions to the case database.

4. Public science education projects

Groups designed the surveys for the general public or relevant social groups, on parasitic infection risks in daily life (e.g., pets, camping, street food). Based on the survey results, students produced videos for the public on topics such as pet parasite prevention and camping-related health risks. We used Rain Classroom to monitor progress and provided iterative feedback. The evaluations from teachers and companions informed further refinements. Outstanding productions were recommended for sharing on campus and external science-outreach platforms, or entered into competitions. This project not only cultivated students’ science-communication skills and teamwork but also boosted their motivation and practical ability.

Assessment: Quality of questionnaires, data analysis, presentations, videos, peer and instructor feedback.

5. Personalized learning pathways

An online platform delivered content tailored to each student based on performance. Three stages were used: (a) baseline quizzes, self-assessments, and diagnostic tests to consolidate foundational knowledge; (b) case-based simulations and decision-making exercises for advanced clinical reasoning; (c) exposure to recent research articles, webinars, and expert talks to update knowledge on parasitic disease control, drug resistance, and vaccines. Platform analytics monitored engagement and guided self-directed learning, enabling instructors to provide targeted content push based on student performance, and feedback to address individual learning gaps, supporting personalized and adaptive instruction.

Assessment: Engagement with learning resources, performance in formative quizzes and simulations, overall exam performance.

Academic performance assessment

The traditional lecture-based cohort (Class of 2022; n=80) and the reformed curriculum cohort (Class of 2023; n = 78) completed parallel final examinations aligned in syllabus coverage, learning objectives, examination blueprint, and difficulty level. Total examination scores were recorded for both cohorts. In addition to overall scores, subdomain scores were derived using the university's examination analysis system, which is routinely used for post-examination quality analysis and curriculum evaluation. The system classifies each examination item according to its associated knowledge point and assessment objective, based on this predefined item-level coding. Total and subdomain scores were summarized descriptively, with mean and standard deviation reported for reference.

Teaching outcomes

Teaching outcomes were evaluated based on student-generated outputs, including questionnaire projects and science-popularization videos. Indicators included project completion, number and validity of survey responses collected, videos produced, and online dissemination. These indicators were used to capture both the production quality and the public educational reach of student-generated outputs.

Student satisfaction and feedback

Student perceptions were assessed using five anonymous 5-point Likert-type questionnaires (from a score of one for strong disagreement to a score of five for strong agreement), each corresponding to one of the five major reform measures, along with overall ratings from the school's anonymous course evaluation system (0–100 scale). Likert-type responses, treated as ordinal data, were analyzed using response frequencies, positive

endorsement rates (scores of 4 or 5), and medians. Open-ended survey responses were analyzed using word-cloud visualization to identify recurring themes and assess alignment with students' pre-course expectations.

Results

Compared with the traditional lecture-based cohort (Class of 2022, n = 80), the reform cohort (Class of 2023, n = 78) achieved higher overall final-examination scores (82.1 ± 6.3 vs. 78.6 ± 6.9 , $t = 2.45$, $p < 0.05$), with improvements particularly evident in parasite life-cycle differentiation, clinical case analysis, and application of prevention and control strategies. For example, the mean score for the 9-point essay on malaria prevention and control in the Belt and Road Initiative context increased from 7.5 to 8.2.

Students completed seven types of survey projects, collected 800 valid responses, and produced six short public education videos, some of which were disseminated on the Bilibili platform (for example: <https://b23.tv/o8a7grk>). One survey project on *Toxoplasma gondii* obtained 622 valid questionnaires, with 73% of respondents expressing a high or very high willingness to share related knowledge with others, indicating broad recognition of the need for public education on this topic (see Supplemental File 1-Figure 1).

The course received 98.301/100 in the school's anonymous course evaluation system, placing it in the top 5% of all offerings. This high level of overall satisfaction was further reflected in post-course anonymous open-ended feedback, a "word cloud" in which the most frequent terms were interesting, clinical, comprehensive, useful, and time (Figure 2).

Across the 5-point Likert-type items assessing the major reform measures, more than 77.95% of responses were rated as "agree" or "strongly agree" (Table 2). Responses

Figure 2: A word cloud regarding students' post-course perspectives and experiences



Table 2: Student evaluation of five major reform measures based on 5-point Likert-type questionnaires

Reform measure	Item	1	2	3	4	5	Median	4–5 (%)
Regular content updates	The updates to the course content, reflecting recent research and epidemic data, contributed to my learning outcomes.	1	2	7	28	40	5	87.2
	The emphasis on high-incidence and emerging parasitic diseases helped deepen my understanding of parasitology.	1	3	8	30	36	5	84.6
	The updates in course content allowed me to apply current research and trends to real-world situations.	2	6	15	28	27	4	70.5
	I can adjust my study plan based on on-going content updates reflecting global and national public health situations.	2	5	15	30	26	4	71.8
	The integration of relevant topics and current discussions increased my engagement with parasitology.	0	2	4	28	44	5	92.3
	I would appreciate receiving further updates on emerging parasitic diseases and related clinical cases.	0	3	4	30	41	5	91.0
Role-play simulation	Assuming different host and transmission roles made the knowledge about the parasite's life cycle more vivid and interesting	1	2	7	28	40	5	87.2
	The simulation helped me move beyond rote memorization to a deeper conceptual understanding.	1	2	8	29	38	5	85.9
	I can accurately depict each developmental stage and transmission route following the exercise.	1	3	11	31	32	4	80.8
	I can draw a complete schematic of the parasite life cycle after the simulation.	1	3	11	31	32	4	80.8
	The interactive format increased my enthusiasm for studying parasite life histories.	2	6	14	30	26	4	71.8
	I hope role-play is incorporated into future modules on other parasite species.	2	6	14	30	26	4	71.8
Case-based learning	Case discussions effectively linked my theoretical knowledge with clinical diagnostic and treatment processes.	0	1	2	26	49	5	96.2
	Analyzing cases helped me understand varied clinical presentations.	1	2	8	30	37	5	85.9
	I am able to extract key clinical details from cases and formulate preliminary diagnostic and intervention plans.	4	8	19	25	22	4	60.3
	I can apply interdisciplinary knowledge (e.g., immunology, epidemiology) to deepen case analysis.	3	8	18	26	23	4	62.8
	Reviewing real-world cases has sparked my continued interest in clinical parasitology research.	1	4	12	32	29	4	78.2
	I would like the case bank to be regularly updated with more complex and novel parasitology cases.	0	1	3	26	48	5	94.9

Real-world application and public education projects	The videos provided memorable prevention recommendations for scenarios such as pet ownership, street food, and outdoor foraging.	1	3	11	29	34	4	80.8
	The accompanying thematic survey helped me review and reinforce key risk and prevention points.	1	2	6	30	39	5	88.5
	I feel confident explaining protective measures to others based on the video content.	2	6	14	31	25	4	71.8
	I am able to contribute to the design of video scripts or survey questions, enhancing my science communication skills.	3	8	18	26	23	4	62.8
	Creating or watching these context-relevant videos increased my interest in health education.	1	3	11	31	32	4	80.8
	I hope to participate in more thematic outreach activities in the future.	2	6	14	30	26	4	71.8
Personalized learning pathways	The push questions targeted my knowledge gaps and helped me consolidate core concepts.	3	7	15	29	24	4	67.9
	The recommended resources improved my learning efficiency and outcomes.	4	8	15	30	21	4	65.4
	I can plan and adjust my study schedule based on the push notifications.	3	8	15	31	21	4	66.7
	The delivered resources helped me for focused practice and monitor my progress.	4	9	17	30	18	4	61.5
	The variety of personalized content sustained my curiosity in parasitology topics.	3	7	14	32	22	4	69.2
	I would like to receive more resource types (e.g., micro-lectures quizzes, interactive tasks).	0	1	1	25	51	5	97.4

Data are presented as frequencies for each response category (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree). Because Likert-type responses are ordinal, item-level results are summarized using medians and positive response rates (scores of 4 or 5).

were concentrated in the upper categories, with median ratings generally at 4 or 5. Regular content updates showed the highest overall positive endorsement rate (82.9%). By contrast, personalized learning pathways showed greater dispersion, with positive endorsement rates ranging from 61.5% to 97.4%, although overall evaluations remained positive.

Discussion

Guided by principles of CBE and constructivist learning theory, this teaching reform was associated with improved academic performance, meaningful student-generated outputs, and high learner acceptance. Pre-course word-cloud analysis identified key learner priorities, including clinical relevance, practice, case-based learning, and analytical thinking, which were closely related to the development of applied knowledge, clinical reasoning, problem-solving, and transferable professional competencies. Post-course word-cloud findings further supported the reform, showing sustained emphasis on clinical content and positive perceptions, described as “interesting”, “comprehensive”, and

“useful”. This suggested that the reform was aligned with students’ professional expectations and was perceived as more engaging and applicable.

Curriculum updates aligned with global and national parasitology trends, combined with student-designed surveys and public education videos, provided authentic, context-rich tasks that encouraged learners to link theoretical knowledge to real-world issues, consistent with constructivist principles. In our digital age, healthcare professionals must navigate evolving online information and contribute to digital transformation in health care.^{11,12} Although students are mainly digital natives, prior studies indicate deficiencies in digital health literacy.¹³ By integrating trending public-health topics, viral discussions, surveys, and educational video projects, the course allowed students to critically assess scientific validity, accuracy, and ethical dimensions while applying parasitology knowledge in practice.¹⁴ Furthermore, public health surveys and science communication videos creatively engaged students in addressing parasite-related risks in contexts familiar to

them—such as pet ownership, food delivery culture, and outdoor exploration—while aligning learning formats with their existing digital proficiencies. This approach exemplified a shift from traditional, instructor-led models to a participatory learning environment where students were both consumers and producers of knowledge. The course supported a holistic approach to enhancing student digital literacy and fostering public-private partnerships, as recommended by Focsa *et al.*¹⁵ However, uneven participation in collaborative tasks occasionally led to variability in skills acquisition and learning outcomes, highlighting the need for clearer role allocation and closer process monitoring.

Role-playing of parasite life cycles effectively addressed one of the course's core challenges: the complexity and high similarity of over 20 parasite species, which are easily confused in traditional lecture-based instruction. Students prepared in advance and actively engaged in simulated transmission scenarios, applying knowledge only when they had a solid understanding of underlying concepts,¹⁶ in line with constructivist learning principles. The activity fostered teamwork, communication, and problem-solving skills, supporting competencies required for clinical practice. However, student survey data (Table 2) show that 71.8% of students rated role-playing positively for increasing enthusiasm and desire to see it in future modules. Response variability indicated that, although most students found the activity engaging, some—particularly introverted learners—may feel less comfortable performing publicly. For instructors, the method requires imaginative scenario design and the ability to provide guidance and corrective feedback to ensure learning objectives are achieved.

CBL was designed to develop the professional competencies of clinical students, as reflected in pre-course word-cloud analysis highlighting “clinical” as a key theme. Student feedback (Table 2), post-course word-cloud analysis, and examination results indicated that CBL effectively applied theory to clinical decision-making. Consistent with Mallory *et al.* and Karim *et al.*,^{17,18} the approach integrated cross-disciplinary knowledge—including anatomy, physiology, immunology, and clinical medicine—while guiding students through stepwise, context-specific problem-solving. Nevertheless, students reported challenges in extracting key clinical details (only 60.3% positive endorsement rate) and integrating interdisciplinary knowledge (only 62.8% positive endorsement rate). Further iterations could involve clinical physicians from relevant departments (e.g., infectious diseases) in case-based teaching to enhance learning by providing authentic clinical perspectives. This approach may

improve students' clinical reasoning and interdisciplinary integration.

For our teachers, a well-designed course, continuously refined through evaluation-based feedback, remains essential for effective instruction.^{19,20} Bhatti *et al.* demonstrated that the online platform Hot Cases improved medical students' learning, highlighting the value of technology-enhanced education.²¹ Building on this evidence, our study integrated personalized learning pathways and a multidimensional evaluation framework via the Rain Classroom online platform. This curriculum not only introduced them to key parasitology knowledge but also equipped them with the competencies required to navigate the digital health landscape effectively. However, personalized learning increased students' extracurricular workload and exposed substantial differences in learner autonomy, with students showing weaker self-regulation benefiting less from this approach.

Limitations

This study has several methodological limitations. Firstly, this study used a cohort-based quasi-experimental design rather than random allocation, and comparisons across different cohorts may have introduced unmeasured baseline differences. Secondly, as a single-institution study involving medical undergraduates from one course, the generalizability of the findings may be limited. Finally, some outcomes were based on self-reported questionnaire data (e.g., Likert scale measurements) and may therefore be subject to response and social desirability bias.

Conclusions

Overall, this reform was associated with higher student engagement, improved clinical reasoning, and closer alignment of parasitology teaching with current public-health issues. Future refinement may focus on involving clinical physicians in case-based teaching, integrating online and offline teaching to provide data-driven personalized guidance, and strengthening scaffolding for collaborative and individualized learning. Other institutions may benefit from integrating student-relevant hot topics, clinically oriented case-based teaching, diverse practical activities, and higher-order thinking training.

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Supplementary materials

Supplement 1. Supplementary File 1

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