RESEARCH ARTICLE

The practical application of "Team-based learning" mode in fundamental medical courses: Medical Immunology as the example

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Abstract

Objective: To systematically implement the team-based learning framework as a replicable model for curriculum innovation in foundational medical disciplines.

Method: The educational intervention research study was conducted from March, 2021 to July, 2021 at Chengde Medical University after approval from the ethics review board of Chengde Medical University, China, and comprised Clinical Medicine students at the Department of Medical Immunology. The two groups had comparable baseline demographic and academic profiles. The intervention in group A was implemented over 15 consecutive academic weeks with 4 theoretical teaching hours per week. Theoretical instruction integrated case-driven inquiry, problem-based learning, role-reversal simulations, and seminar-style discourse. Practical training adopted a hierarchical structure, encompassing core laboratory experiments, elective investigative projects, and university-level innovation initiatives. Multimodal methodologies were utilised to optimise knowledge retention. Positive value of respecting life enriched case studies were embedded to integrate professional ethics and humanistic values, while a competency-centric evaluation system tracked team-based processes and individual skill progression. Those in group B received a conventional teacher-centred instructional model characterised by instructor-dominated didactic lectures, supplemented with regular homework assignments.

Results: The two groups of students were comparable across all baseline characteristics (Table 1 for details). Post-intervention evaluations demonstrated overwhelmingly superior outcomes for the TBL approach. Satisfaction rates in the TBL group consistently exceeded 90% (reaching up to 99.4%) across theoretical and practical domains, significantly outperforming the LBL group (satisfaction rates: 52.8%-66.3%; all inter-group comparisons $p<0.001$). Empirical outcomes demonstrated significant improvements in learners' autonomous knowledge acquisition, collaborative problem-solving proficiency, translational research capabilities, and interdisciplinary innovation competencies. The team-based learning framework also fostered enhanced clinical reasoning and ethical awareness among the participants.

Conclusion: The team-based learning paradigm was found to be a transformative pedagogical tool, providing a robust foundation for competency-driven medical education. Its scalable design offered actionable insights for curriculum reform across foundational medical and allied health disciplines, aligning with the evolving demands of global healthcare education.

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Introduction

Within the framework of contemporary medical pedagogy, foundational medical disciplines serve as the cornerstone for cultivating a new generation of healthcare professionals. Among these, Medical Immunology emerges as a pivotal interdisciplinary nexus, transcending its historical roots in anti-infective mechanisms to encompass cutting-edge intersections with molecular biology, translational medicine, and biotechnological innovation. As a critical conduit bridging theoretical constructs and clinical practice, the discipline of Medical Immunology empowers learners to decipher pathogenic mechanisms, formulate evidence-based intervention strategies, and master advanced methodologies in biomedical research competencies indispensable for future pioneers in precision medicine.

Nevertheless, the inherent abstraction and epistemological complexity of immunological principles, compounded by rapid advancements in frontier knowledge domains, present formidable pedagogical challenges. Conventional didactic approaches often fail to facilitate the integration of multidimensional concepts, resulting in fragmented comprehension and diminished learner engagement.[1,2] To address this paradigm, an innovative team-based learning (TBL) framework was designed, synergising problem-driven inquiry, collaborative knowledge construction, and adaptive split-class dynamics.[3-6] This pedagogical

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ecosystem was further reinforced by a competency-centric assessment matrix, strategically engineered to catalyse critical analysis, foster intellectual autonomy, and incubate translational innovation.The current study was planned to systematically implement the TBL framework as a replicable model for curriculum innovation in foundational medical disciplines.

Subjects and Methods

The study employed a cluster-randomized design. All participants were second-year Clinical Medicine students enrolled in the compulsory Medical Immunology course during the 2021 spring semester. The student cohort for this academic year consisted of six parallel classes. Upon university admission, these students had been randomly assigned to administrative classes based on gender and Gaokao scores, ensuring baseline equivalence across classes. From these six classes, two were randomly selected (using computer-generated random numbers) to participate in the study, preserving the existing administrative class structure to minimize logistical disruption. One class was randomly assigned to the experimental group, and the other to the control group.

Due to the logistical constraints of the natural educational setting and the need to maintain the integrity of existing class structures, the sample size was determined by the number of students enrolled in two parallel classes of the academic year. A post-hoc power analysis was conducted based on the observed primary outcome (e.g., the proportion of students reporting high satisfaction with critical thinking cultivation: 98.16% in TBL vs. 52.76% in LBL). Assuming an intra-cluster correlation coefficient (ICC) of 0.05, the achieved power for detecting this difference exceeded 99%, indicating that the sample size of 326 students (2 clusters) was sufficient to detect a large effect size with high probability.

Control group B was subjected to the conventional lecture-based learning (LBL) model characterised by instructor-dominated didactic lectures, supplemented with regular homework assignments. This pedagogy positioned the teacher as the primary knowledge transmitter, delivering content through unidirectional knowledge transfer from instructor to students. The intervention was implemented over 15 consecutive academic weeks with 4 theoretical teaching hours per week. Course content strictly adhered to Medical Immunology (7th Edition, People's Medical Publishing House)[7] without curriculum modifications. All instructional decisions, including pace, content emphasis, and questioning patterns, remained under teacher control. Student performance was evaluated exclusively through summative assessment (100% weightage), consisting of a comprehensive closed-book final examination.

In group A, the TBL methodology was employed for instruction, During the inaugural session, the learners were oriented towards this transformative pedagogical model through a structured induction process. Cohorts of 4-6 participants were algorithmically assembled to achieve heterogeneous intra-team diversity (gender, cognitive styles, and academic proficiencies) while maintaining homogeneous inter-team parity — a design ensuring equitable competitive dynamics and maximising collaborative synergies. Each team elected a designated leader, selected for demonstrated organisational acumen and leadership potential, to orchestrate collective problem-solving endeavours. Crucially, this team configuration remained invariant across both theoretical discourse and experimental modules throughout the academic term, thereby cultivating sustained intellectual cohesion and accountability.

The Medical Immunology curriculum incorporated four evidence-based teaching methodologies to enhance conceptual understanding and foster critical thinking. A cornerstone of this approach was the implementation of case-driven collaborative learning, wherein the Medical Immunology Department developed a comprehensive repository of clinically relevant cases aligned with each curricular module. Prior to each session, case materials and guided inquiry questions were disseminated through institutional learning platforms, prompting teams to conduct structured literature reviews and formulate preliminary hypotheses. In-class activities followed a tripartite protocol: teams delivered concise presentations outlining their analytical frameworks, engaged in cross-group debates addressing conceptual contradictions (e.g., the dual regulatory roles of immune responses in coronavirus diseas-2019 [COVID-19] pathogenesis), and participated in instructor-facilitated syntheses to consolidate fragmented insights into unified theoretical models. For instance, the "Historical Perspectives in Immunization" module employed comparative analyses of smallpox eradication campaigns, COVID-19 containment strategies, and serum therapy mechanisms, accompanied by probing questions examining the disciplinary evolution from microbiology to immunology, herd immunity threshold calculations, and modern adaptations of passive immunisation principles.

Complementing this framework, problem-based cognitive engagement strategies were deployed to address complex immunological paradoxes. The Forssman phenomenon[8] served as a paradigmatic case study, wherein rabbits immunised with guinea pig organ suspensions exhibited cross-reactive antibodies against sheep erythrocytes. The students were challenged to elucidate the mechanistic basis of heterophile antigen interactions and critically evaluate the immunological classification of normal saline under homeostatic conditions. Through iterative cycles of hypothesis generation and peer-reviewed argumentation, the learners refined their scientific reasoning capacities while bridging abstract concepts with experimental evidence.

To mitigate the inherent challenges of immunological abstraction, role-reversal didactic strategies were integrated into the innate immunity curriculum. Teams were randomly assigned cellular components (e.g., natural killer [NK] cells, dendritic cells) and tasked with autonomously constructing digital concept maps, producing micro-lectures addressing threshold concepts, and delivering peer teaching sessions. A dual evaluation system was implemented, combining peer assessments of conceptual clarity (40%) with faculty evaluations using standardised rubrics (60%), thereby fostering accountability and metacognitive reflection.

Finally, seminar-style historical inquiry anchored students in the discipline's foundational breakthroughs. Lots of Nobel laureates and frontier knowledge sources are related to Medical Immunology subject. The teacher introduced great discoveries that won the Nobel Prize to the students in related chapters, guided them to select important relevant content, like that related to antibody in 1901[9], 1960[10], 1972[10] and 1987,[11] content about MHC (Major Histocompatibility Complex) in 1980[12] and 1996,[13] content about hot topics, such as toll-like receptors in 2011[14] and negative regulation of immunity to treat tumour in 2018.[15] The teachers guided the students about consulting files about the study background, critical experiments, study significance and inspirations, to raise relevant questions, and complete the research report. Team representative performed their PPT (PowerPoint) and discussion, while the teacher and other teams marked their performance.

Collectively, these methodologies transformed passive knowledge acquisition into an active, collaborative process, aligning with modern pedagogical principles of constructivist learning and competence-based education. The integration of digital tools, structured debate formats, and evidence-driven assessment frameworks ensured both conceptual mastery and the development of transferable analytical skills essential for future medical practice.

Guided by the Undergraduate Medical Education Standards for Clinical Medicine Majors (2016 Edition)[16] — which mandated the cultivation of scientific rigour, clinical proficiency, societal health awareness, and professional ethics — the current study re-engineered practical training through a TBL framework. Traditional laboratory instruction, historically subordinated to theoretical coursework and dominated by repetitive verification experiments, was transformed into a dynamic platform for fostering innovation and translational competencies.

In core laboratory modules, collaborative workflows replaced passive replication tasks. Pre-assigned teams engaged in hypothesis-driven experimentation, with roles systematically allocated to ensure accountability (e.g., protocol execution, data documentation, safety compliance). For instance, during lymphocyte isolation protocols, the teams collaboratively optimised centrifugation parameters and viability assays through iterative problem-solving, documenting individual contributions via digitally authenticated task logs. Post-lab cross-team validation sessions identified methodological discrepancies, cultivating critical appraisal skills while reinforcing procedural standardisation.

To bridge foundational techniques with clinical applications, a tiered elective system was implemented. Students pursuing advanced modules — such as murine immunisation protocols or hepatitis B surface antigen detection via enzyme-linked immunosorbent assay (ELISA) — progressed through a scaffolded design process, comprising literature-curated methodology review, peer-defended experimental proposals, and real-time digital documentation using electronic lab notebooks (ELNs). High-performing cohorts extended their training through provincial innovation projects, integrating computational tools (e.g., epitope prediction algorithms) with wet-lab validation under dual mentorship from basic and clinical immunologists.

The innovation research initiative, grounded in TBL principles, facilitated scientific engagement among students. This programme identified and supported undergraduates demonstrating research aptitude, guiding them through the application and leadership processes of collegiate innovation projects. Through structured participation, students cultivated the ability to integrate theoretical frameworks with practical experimentation while developing critical analysis and innovative problem-solving competencies.

Given the abstract nature and interconnected concepts inherent in Medical Immunology, coupled with the complexity of its scientific terminology, instructors facilitated team-based mind mapping exercises. Collaborative groups systematically deconstructed curriculum components — such as antibody structure-function correlations, complement activation pathways, and immune system organisation — into visual schematics. These diagrams integrated textual explanations, molecular visualisations, and chromatic coding to enhance conceptual clarity. This pedagogical tool significantly improved students' knowledge integration capabilities, promoted cognitive organisation, and stimulated proactive engagement with immunological studies, while simultaneously cultivating analytical reasoning and innovative thinking competencies.

The Wenjuanxing platform,[17] a software to send and collect test paper, was integrated into Medical Immunology courses for formative assessments and longitudinal competency tracking. Instructors administered classroom quizzes, modular examinations, and milestone evaluations through this system, analysing performance metrics to provide adaptive feedback. This data-driven approach guided students in consolidating complex immunological concepts while enhancing engagement, thereby enabling real-time assessment accuracy and optimised instructional efficacy.

The growth record portfolio (GRP) systematically documented students' competency development trajectories, including phased academic outcomes, persistent conceptual challenges, and strategic learning adaptations. Following initial Medical Immunology modules (approximately 3 chapters), the learners curated entries detailing acquired competencies, unresolved knowledge gaps, and evidence-based study plans. Faculty mentors conducted structured portfolio reviews, providing individualised guidance to enhance metacognitive reflection and self-regulated learning behaviours. This cyclical documentation-analysis process cultivated comprehensive skill development through iterative improvement cycles.

The Immunology Department prioritised the development of pedagogical resources through collaborative faculty efforts. Building upon university-endorsed open courseware in Medical Immunology, educators collaboratively developed micro-lectures addressing threshold concepts (minimum one per chapter), curated clinical case studies, designed chapter-specific problem sets, and produced experimental demonstration videos. These resources were systematically organised into digital repositories: micro-lecture archives, case banks, video libraries, and question databases. A resource-based learning (RBL) framework was implemented, distributing materials via online platforms for guided independent study while maintaining structured offline instruction. This blended learning paradigm significantly enhanced self-directed learning competencies.

The Medical Immunology curriculum instituted a multidimensional assessment framework that transcended singular summative metrics. The restructured evaluation system allocated 70% weightage to comprehensive final examinations, while incorporating 30% formative assessments encompassing faculty evaluations of academic engagement, cross-team peer reviews, and reflective self-appraisals. A distinctive feature of this paradigm was the collective scoring mechanism, wherein individual performance metrics directly informed team-level formative assessment outcomes. This approach not only operationalised the principles of continuous competency development, but also fostered pedagogical transparency, thereby enhancing students' agency in monitoring their knowledge integration processes and innovation capabilities.

At the end of the semester, questionnaires were distributed by Wenjuanxing to students in both the groups about theoretical and practical teaching parts. Student satisfaction and competency development were evaluated through an 11-domain post-intervention questionnaire. Each domain featured a tripartite response scale — Satisfied/General/Dissatisfied. Statistical analysis involved calculating response frequencies per domain, while intergroup differences were assessed using chi-square test through SPSS 26.0 (Statistical Package for the Social Sciences).

Results

Of the 326 students, 163(50%) were in each of the two groups. Satisfaction rates in group A consistently exceeded 91.41% (149/163) in theoretical sessions and surpassed 95.09% (155/163) in practical modules compared to 58.28% (95/163)-66.26% (108/163) and 52.76 (86/163)-64.42% (105/163), respectively in group B.

In theoretical instruction, Group A demonstrated significantly higher satisfaction than Group B in cultivating independent exploration skills (92.02% [150/163] vs. 61.35% [100/163]; $P < 0.001$) and in learning engagement (91.41% [149/163] vs. 58.28% [95/163]; $P < 0.001$).

For practical training, a significantly higher proportion of students in Group A endorsed its effectiveness in fostering clinical knowledge integration compared to Group B (97.55% [159/163] vs. 64.42% [105/163]; $P < 0.001$). Similarly, Group A showed superior results for developing problem-solving capabilities (95.71% [156/163] vs. 60.74% [99/163]; $p<0.001$).

Critical competencies, such as innovative thinking (96.93% [158/163] in group A vs. 58.90% [96/163] in group B; $P < 0.001$) and critical analysis (98.16% [160/163] vs. 52.76%

[86/163] in group B; P < 0.001) highlighted TBL's alignment with modern medical education objectives. Notably, 99.39% (162/163) of students in group A reported enhanced communication skills, contrasting sharply with the 53.99% (88/163) approval in group B, and the difference is statistically significant (*p*<0.001).

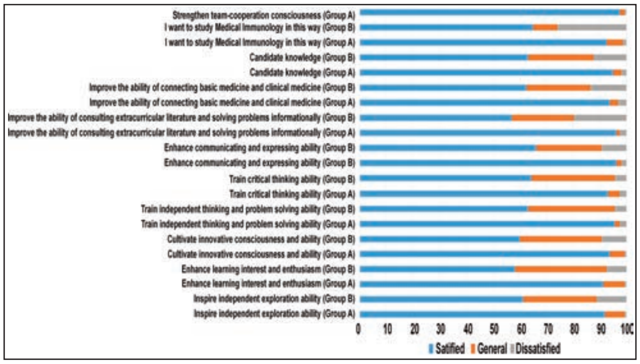

Figure-1: The students' evaluation in theory class.

Table-1: Baseline Characteristics of Participants and Inter-group Comparison.

Characteristic	Experimental Group	Control Group	*p*-value
Mean Age (years)	20.1 ± 0.8	20.2 ± 0.7	0.321
Gender, n (%)			0.745
Male	79 (48.5)	82 (50.3)	
Female	84 (51.5)	81 (49.7)	

p>0.05 indicates no statistically significant difference in all baseline characteristics between the two groups, confirming comparability.

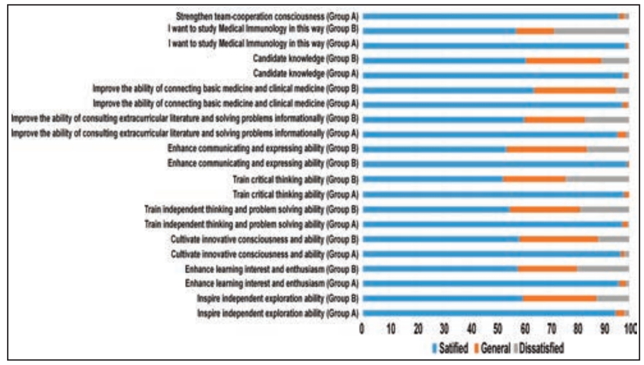

Figure-2: The students' evaluation in practice class.

While dissatisfaction rates for TBL remained minimal (0%-1.84% [0/163-3/163]) in group A, those in group B exhibited higher discontent, particularly in practical training (4.91%-28.22% [8/163-46/163]). Areas for TBL refinement included addressing sporadic disengagement in theoretical modules, details are in Figure 1-2 and Table 2.

Discussion

The comparative student evaluation data (Table 2) provides compelling empirical evidence for the profound impact of the TBL pedagogy compared to the LBL mode across multiple critical dimensions of medical education. The results consistently demonstrate overwhelmingly higher levels of student satisfaction with the TBL approach, coupled with significantly lower levels of dissatisfaction, suggesting a paradigm shift is warranted in instructional

Table-2: The students' evaluation on "team-based learning" mode (group A) versus students' evaluation on traditional lecture mode (group B) (n (%) n=163.

Contents of evaluation	Satisfied		General		Dissatisfied		*p*-value
	Theory	Practice	Theory	Practice	Theory	Practice	
Inspire independent exploration ability (A)	150(92.02)	155(95.09)	12(7.36)	5(3.07)	1(0.61)	3(1.84)	<0.001
Inspire independent exploration ability(B)	100(61.35)	98(60.12)	45(27.61)	45(27.61)	18(11.04)	20(12.27)	
Enhance learning interest and enthusiasm(A)	149(91.41)	157(96.32)	13(7.98)	4(2.45)	3(1.84)	2(1.23)	<0.001
Enhance learning interest and enthusiasm(B)	95(58.28)	95(58.28)	56(34.36)	36(22.09)	12(7.36)	32(19.63)	
Cultivate innovative consciousness and ability(A)	153(93.87)	158(96.93)	9(5.52)	2(1.23)	1(0.61)	3(1.84)	<0.001
Cultivate innovative consciousness and ability(B)	98(60.12)	96(58.90)	50(30.67)	48(29.45)	15(9.20)	19(11.66)	
Train independent thinking and problem solving ability(A)	156(95.71)	159(97.55)	3(1.84)	3(1.84)	4(2.45)	1(0.61)	<0.001
Train independent thinking and problem solving ability(B)	103(63.19)	90(55.21)	53(32.52)	43(26.38)	7(4.29)	30(18.40)	
Train critical thinking ability(A)	152(93.25)	160(98.16)	7(4.29)	3(1.84)	4(2.45)	0(0)	<0.001
Train critical thinking ability(B)	105(64.42)	86(52.76)	51(31.29)	38(23.31)	7(4.29)	39(23.93)	
Enhance communicating and expressing ability(A)	157(96.32)	162(99.39)	3(1.84)	1(0.61)	3(1.84)	0(0)	<0.001
Enhance communicating and expressing ability(B)	108(66.26)	88(53.99)	40(24.54)	49(30.06)	15(9.20)	26(15.95)	
Strengthen team-cooperation consciousness	159(97.55)	157(96.32)	3(1.84)	3(1.84)	1(0.61)	3(1.84)	
Improve the ability of consulting extracurricular literature and solving problems informationally(A)	158(96.32)	156(95.71)	2(1.23)	5(3.07)	3(1.84)	2(1.23)	<0.001
Improve the ability of consulting extracurricular literature and solving problems informationally(B)	93(57.06)	99(60.74)	38(23.31)	37(22.70)	32(19.63)	27(16.56)	
Improve the ability of connecting basic medicine and clinical medicine(A)	153(93.87)	159(97.55)	5(3.07)	3(1.84)	5(3.07)	1(0.61)	<0.001
Improve the ability of connecting basic medicine and clinical medicine(B)	102(62.58)	105(64.42)	39(23.93)	50(30.67)	22(13.50)	8(4.91)	
Consolidate knowledge(A)	155(95.09)	160(98.16)	5(3.07)	2(1.23)	3(1.84)	1(0.61)	<0.001
Consolidate knowledge(B)	103(63.19)	100(61.35)	40(24.54)	46(28.22)	20(12.27)	17(10.43)	
I want to study Medical Immunology in this way(A)	151(92.64)	161(98.77)	10(6.13)	1(0.61)	2(1.23)	1(0.61)	<0.001
I want to study Medical Immunology in this way(B)	106(65.03)	94(57.67)	15(9.20)	23(14.11)	42(25.77)	46(28.22)	

design.

The current comprehensive evaluation unequivocally demonstrates that the TBL mode is perceived by students as vastly superior to LBL in inspiring deep learning, developing essential cognitive and practical skills, fostering engagement and innovation, promoting teamwork, enhancing information literacy, integrating basic and clinical sciences, and consolidating knowledge. The magnitude and consistency of the positive outcomes associated with TBL strongly advocate for its wider adoption and integration into medical curricula. Its ability to actively engage students, foster accountability within teams, and apply knowledge to solve complex problems aligns perfectly with the goals of modern medical education, preparing students more effectively for the collaborative and problem-based nature of clinical practice. The high levels of student endorsement for continuing with TBL further validate its acceptance and perceived value.[18]

Medical Immunology curriculum gives classroom instruction a key position and a principle role, integrating it with the value of respecting life and positive mindset in the process of competent ability training and creativity development. In this process, students are cultivated into compassionate professionals who respect life, cherish life, and are dedicated to healing and rescue, as well as into specialized talents equipped with proactive thinking, problem-solving abilities, and an exploratory spirit that dares to innovate.[19]

According to collective preparation for lectures, the teaching department uniformly discussed certain knowledge points of the value of respecting life and positive mindset nature that were included in every chapter of the Medical Immunology textbook. While based on humanistic literacy, major advances, and recent scientific achievements of department members, the value of respecting life and positive mindset teaching case database has been established by collecting literal materials organised by department faculty. For example, Dr. Lin Qiaozhi pioneered the umbilical vein exchange transfusion technique through dedicated research to treat newborns with haemolytic disease. Her respect for life and profound love for the medical profession serve as an inspiration for healthcare workers to strive for exploration and innovation. For instance, while erythropoietin can stimulate red blood cell production, its use as a doping agent is illegal—a reminder that integrity must always be upheld in practice.

The course also introduces several immunologists who were awarded the Nobel Prize in Physiology and Medicine, such as Robert Koch, who discovered multiple pathogenic bacteria and established the tuberculin test (1905), Harald zur Hausen, who discovered that human papillomavirus (HPV) can cause cervical cancer (2008), James P. Allison and Tasuku Honjo, who discovered a new therapy by immunosuppressive factor to treat tumours (2018). Listing their arduous and significant research process in the fields of infection immunity, basic immunity and tumour immunity can lead students to reflect more, question boldly, and act fearlessly. The target is to stimulate their creativity spirit and practice ability in order to lay a foundation for fostering highly-qualified and top-notch professional.[20]

The course also shed light on the COVID-19 pandemic, from its pathogenic immune mechanism to a series of public health, psychological and socioeconomic problems, to help students analyse and solve questions based on dialectical thinking, making them realise that in order to become competent doctors, they should not only master comprehensive professional knowledge and skills, but also need to have a highly-developed sense of social responsibility.

Conclusion

The TBL paradigm was found to be a transformative pedagogical tool, providing a robust foundation for competency-driven medical education. Its scalable design offered actionable insights for curriculum reform across foundational medical and allied health disciplines, aligning with the evolving demands of global healthcare education. The TBL mode could not only lay the foundation for promoting the students' professional knowledge, but also played critical role in cultivating high-quality, high-capacity applied talents.

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Author Contribution:

XZ: Drafting and revision.

SD & LW: Data acquisition and analysis.

JW: Data interpretation.

SM: Design.

YL: Final approval.

LJX: Design and agreement to be accountable for all aspects of the work