

Reform Exploration of a Framework Integrating PBL with Virtual Simulation for Optimizing the Orthopedic Teaching Model at the Undergraduate Stage

Shanlang Li¹, Kangqi Xie¹, Dianbo Yu¹, Haidong Zhou², Changtai Luo¹, Huade Ma¹, Mingzhe Yao¹, Jihua Wei^{1*}

¹Affiliated Hospital of Youjiang Medical University for Nationalities, Baise, China

²Graduate School, Guangxi Medical University, Nanning, China

Email: *1261290953@qq.com

How to cite this paper: Li, S. L., Xie, K. Q., Yu, D. B., Zhou, H. D., Luo, C. T., Ma, H. D., Yao, M. Z., & Wei, J. H. (2026). Reform Exploration of a Framework Integrating PBL with Virtual Simulation for Optimizing the Orthopedic Teaching Model at the Undergraduate Stage. *Creative Education*, 17, 1912-1923.

<https://doi.org/10.4236/ce.2026.1710108>

Received: August 13, 2026

Accepted: October 16, 2026

Published: October 19, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.

This work is licensed under the Creative Commons Attribution-NonCommercial International License (CC BY-NC 4.0).

<http://creativecommons.org/licenses/by-nc/4.0/>



Open Access

Abstract

Orthopedic teaching at the undergraduate stage spans anatomy, imaging, bio-mechanics, and surgical procedures, requiring students not only to comprehend complex anatomical structures but also to master clinical practical skills. However, constrained by insufficient practical training conditions, clinical ethical constraints, and rigid traditional teaching modes, orthopedic teaching for undergraduates has long been plagued by challenges including abstract and hard-to-grasp knowledge content, limited hands-on practice opportunities, the disconnection between theory and clinical practice, and low learning initiative among students. Problem-based learning (PBL) takes real clinical cases as the entry point and guides students to carry out active inquiry in group settings. Supported by three-dimensional digital technology, virtual simulation converts complex anatomical structures, fracture injuries, and surgical workflows into repeatable, immersive digital practice scenarios. Teaching reform practices in physiology, internal medicine, dermatology, emergency medicine, and other disciplines have shown that the integration of the two approaches can effectively stimulate students' enthusiasm for learning and improve their knowledge mastery and comprehensive practical competence. Drawing on existing teaching reform experience and the practical realities of undergraduate orthopedic teaching at local medical colleges, this paper puts forward a conceptual integrated teaching framework of "tiered clinical case library, stratified virtual simulation training, multi-dimensional feedback-based assessment", and maps out a complete teaching cycle spanning pre-class, in-class, and post-class phases. Built on Kirkpatrick's four-level evaluation model, the framework incorporates

an assessment system combining teacher assessment, peer assessment, and self-assessment. The educational effects of this framework remain theoretical, and further empirical research is needed to confirm its practical value. This work aims to provide insights for the reform of clinical orthopedic courses at the undergraduate stage.

Keywords

PBL, Virtual Simulation, Orthopedic Teaching, Teaching Model, Teaching Reform

1. Background

Orthopedics is a core course for clinical medicine undergraduates, covering sub-specialties including trauma, joint disorders, and spinal diseases. Satisfactory learning outcomes cannot be achieved merely by mechanical memorization; this course imposes high requirements on students' three-dimensional spatial imagination, image-reading competence, and surgical operational skills.

Nevertheless, most orthopedic teaching still adopts the conventional mode: teachers give lectures via PowerPoint presentations and play surgical videos for teaching purposes. Practical difficulties remain: human anatomical specimens entail high procurement and maintenance costs and are easily damaged or worn. From an ethical perspective, orthopedic trauma and similar clinical conditions cannot be used for teaching drills on real patients. Furthermore, residents and professional-degree master's students occupy a large number of clinical posts, which further reduces hands-on practice opportunities for undergraduate students.

Simply put, PBL moves away from the one-way knowledge instillation by teachers and drives learning via authentic clinical problems. Students are divided into groups to jointly retrieve literature, discuss clinical cases, and formulate solutions through independent thinking. Virtual simulation fills the gap in practical training. Relying on three-dimensional modeling and human-computer interaction, digital platforms enable repeated simulation and trial-and-error practice for scenarios such as fracture displacement and surgical operations that cannot be performed repeatedly in real clinical contexts.

Many medical institutions in China have applied this combined teaching model to physiology, pathology, emergency medicine, and other courses, yielding favorable teaching outcomes (Feng et al., 2023; Jiang et al., 2026; Liu et al., 2024; Zheng et al., 2026). By contrast, in the field of orthopedics, both PBL and virtual simulation are individually supported by systematic reviews. However, studies investigating their combined application remain scarce, with most focusing on residents and postgraduate trainees (Roy et al., 2025; Xiong et al., 2025). A randomized controlled trial (RCT) of orthopedic trauma conducted by Xue et al. (2026) found that this combined teaching approach improved students' theoretical knowledge,

practical skills, and critical thinking, but its sample size was limited. Notably, evidence supporting this integrated teaching model at the undergraduate orthopedic level remains sparse and warrants further empirical validation.

Against this backdrop, and in light of the actual conditions of local medical colleges, this paper draws on reform experience from related disciplines to construct an integrated teaching model suitable for orthopedics, outline its complete implementation pathway, and offer references for teaching innovation in surgery-related disciplines. The educational benefits of this model have not been empirically validated, and further practical studies are needed to substantiate its real teaching effects.

2. Practical Dilemmas Facing Traditional Orthopedic Teaching

2.1. Main Practical Problems in Traditional Orthopedic Teaching

The phenomenon of “difficult teaching for teachers and difficult learning for students” in orthopedic classrooms arises from overlapping contradictions among the characteristics of disciplinary knowledge, the supply of practical training resources, classroom organization, and assessment and evaluation systems.

Orthopedics involves complex relationships among bones, joints, blood vessels, and nerves. Textbook two-dimensional illustrations and physical specimens can only present morphological features from fixed angles and fail to dynamically reproduce the full process of injury onset, displacement progression, and tissue repair. Some students tend to mechanically memorize classification criteria yet are unable to build three-dimensional anatomical models in their minds, and have only a superficial understanding of the evolutionary logic behind injuries. This constitutes a persistent bottleneck for orthopedic teaching (Wang et al., 2022).

Orthopedic operations carry high clinical risks, so undergraduates can rarely participate in core surgical procedures in real clinical settings. Human anatomical specimens are expensive to purchase and maintain; dissection causes irreversible damage and thus cannot support large-scale, repeated training. Intraoperative massive hemorrhage, accidental injury of vital nerves, and other adverse events are strictly avoided in clinical work and cannot be used as teaching simulation materials. Accordingly, students lack a training medium for emergency-response thinking in high-risk clinical scenarios (Jiang et al., 2026; Sun et al., 2022).

Traditional medical education separates theoretical teaching and clinical internship into discrete stages. When students finish orthopedic courses, most of them have not yet begun clinical ward rotations. Lacking real clinical experience, they acquire fragmented knowledge and struggle to independently construct the complete logical chain of “anatomical morphology, injury pathology, diagnosis and treatment, prognosis evaluation”. As a result, the cultivation of systematic clinical thinking lags behind (Zheng et al., 2026).

Even when PBL group discussions are included, ambiguous role division can lead to imbalanced task allocation within groups. Only a few students take on

most of the literature review and presentation work, while other group members participate passively. Such divergence in individual learning gains undermines the effectiveness of collaborative group learning (Wei & Wang, 2025).

At present, closed-book final examinations remain the core assessment method for most orthopedic courses. Assessments mainly focus on knowledge memorization, and single paper-and-pencil examinations cannot objectively evaluate students' comprehensive competence. Formative assessment accounts for too small a proportion; students' performance in group discussions, practical training, and case analysis is not fully reflected. Such an assessment orientation encourages rote memorization while discouraging the cultivation of thinking and practical skills.

2.2. Theoretical Basis for Combining PBL with Virtual Simulation in Orthopedic Teaching Reform

This teaching model is designed based on constructivism and situated cognition theories: knowledge is not transmitted one-way by teachers but actively internalized and constructed by learners within highly simulated clinical contexts (Feng et al., 2023). PBL puts forward authentic clinical problems to promote group-based literature review and case discussion and fosters students' independent inquiry competence and critical thinking. Featuring immersion, interactivity, and repeatability, virtual simulation transforms phenomena that are difficult to observe or practice repeatedly in reality into digital training tools (Li & Gao, 2024).

Physiology teaching reform provides valuable references. The teaching framework of “tiered clinical case library, stratified virtual experiments, multidisciplinary cross-cutting tasks” bridges the gap between theoretical knowledge and clinical application (Zheng et al., 2026). Controlled educational studies in pediatrics demonstrate that the combination of virtual scenario simulation and PBL can enhance students' knowledge base, practical competence, and satisfaction with classroom learning (Peng et al., 2021). In dermatology, a study applying virtual simulation alongside the modified SPLICE pedagogy—an active-learning approach related to but distinct from PBL—also found improved outcomes in clinical practical teaching (Wang & Sun, 2025). Related quasi-experimental studies abroad also show that this combined teaching model can positively promote learners' critical thinking, problem-solving ability, and learning self-efficacy (Song & Kim, 2023). The RCT by Xue et al. (2026) in orthopedic trauma adds further preliminary evidence supporting the transferability of the combined PBL-virtual simulation teaching model. As such, adapting proven integrated teaching frameworks from other disciplines to fit the professional characteristics of orthopedics is supported by both theoretical grounding and preliminary empirical data.

In this paper, Kirkpatrick's four-level evaluation model is introduced to build the evaluation framework of teaching effectiveness from four dimensions: reaction level (students' subjective satisfaction), learning level (knowledge mastery), behavior level (practical skill application), and results level (programme-level anticipated outcomes, such as course objective attainment and students' orthopedic

clinical readiness). This study applies an adapted version of Kirkpatrick's model, where the results level is designed not to re-evaluate individual competence, but to measure programme-level outcomes. Given the conceptual nature of the framework, such outcomes remain theoretical and call for further empirical validation. PBL raises questions and prompts thinking, while virtual simulation provides a practical medium. Together they act on the cognitive, affective, and behavioral levels, forming a complementary closed-loop and offering a feasible reform approach to address prominent problems in orthopedic teaching.

3. Construction and Implementation Pathway of the Integrated Teaching Model

Drawing on mature teaching reform frameworks from other disciplines in China and considering the professional characteristics of orthopedics, this study establishes the overall teaching pathway of "tiered clinical case library, stratified virtual simulation training, multi-dimensional feedback-based assessment". Implementation is divided into three stages: pre-class preparation, in-class discussion and practice, and post-class consolidation and extension.

3.1. Development of a Tiered Orthopedic Virtual Clinical Case Resource Library

Teaching resources are the foundation. Cases should be diverse and match students' learning levels at different stages. With reference to textbooks and domestic clinical diagnosis and treatment guidelines, teaching cases are divided into three levels: basic, advanced, and comprehensive.

Basic cases, such as femoral neck fractures in older adults, are designed to train students in virtual consultation, three-dimensional CT image interpretation, and fracture classification, with emphasis on identifying the routes of blood vessels and nerves around fracture sites to consolidate basic knowledge. Advanced cases include preoperative planning for knee osteoarthritis. On the virtual platform, students are required to review patient history, interpret imaging data, and select appropriate surgical approaches according to patient conditions. Comprehensive cases involve open fractures complicated by intraoperative massive hemorrhage, peripheral nerve injury, and other sudden critical scenarios. These are no longer limited to standardized procedures; training priorities lie in students' rapid injury assessment, emergency response, and other clinical decision-making abilities.

In addition to case materials, supporting modules are developed simultaneously, including a fracture reduction simulation module, a virtual internal fixation prosthesis operation module, and an intraoperative emergency scenario simulation module. Meanwhile, graded and progressive PBL question chains and multi-dimensional, multi-agent assessment scales are compiled to ensure the smooth implementation of the entire teaching process.

All three tiers of cases follow a uniform five-step PBL workflow: case trigger, individual inquiry, group synthesis, facilitator-led debriefing, and linked simula-

tion task. Basic cases are built around common clinical presentations, such as a femoral neck fracture in older adults. For this tier, individual inquiry centers on anatomical structure, blood supply, and fracture classification; group work yields a preliminary diagnosis and initial management plan. The facilitator-led debriefing addresses misclassification errors and reinforces key neurovascular anatomy, followed by a linked simulation task covering virtual consultation and 3D CT image interpretation. At the advanced tier, cases are framed around preoperative planning scenarios, such as knee osteoarthritis. Individual inquiry addresses surgical indications and imaging measurements, and group collaboration develops a comprehensive preoperative plan. During the debriefing, the facilitator provides critical feedback on procedure selection, and the corresponding linked simulation task allows students to practice virtual prosthesis placement and surgical approach selection. Comprehensive cases are anchored in high-acuity emergency scenarios, such as an open fracture complicated by massive hemorrhage. Individual inquiry prioritizes rapid injury assessment and damage control principles, and group work formulates an integrated resuscitation and surgical plan. The debriefing highlights clinical priority setting and interprofessional team communication, paired with a linked simulation task involving intraoperative emergencies.

3.2. Full-Process Implementation of Staged Teaching

3.2.1. Pre-Class Preparation

Teachers conduct collective lesson planning, develop teaching cases, design PBL question chains, debug teaching resources on the virtual simulation platform, and assign pre-class tasks. Students are divided into learning groups, with a clear division of labor among members. They familiarize themselves with basic operations of the virtual simulation platform in advance, log in to the platform, and complete assigned tasks. Each group divides the work of reviewing textbooks, clinical guidelines, and literature and produces a report after group discussion. Teachers retrieve pre-class data from the back-end of the virtual simulation platform, analyze student learning outcomes and task completion, identify common knowledge weaknesses in the class, and dynamically adjust the focus of in-class discussion instead of rigidly following a predetermined lesson plan (Li & Gao, 2024).

3.2.2. In-Class Discussion and Practical Training

The class organically integrates group presentations and discussions, virtual simulation practice, emergency scenario drills, and review and correction of misconceptions. Each group presents its case analysis results in turn, and groups question one another. After the presentations, students switch roles and enter the virtual simulation system as clinicians, completing a series of operations such as virtual consultation, physical examination, image interpretation, and fracture reduction.

Throughout the process, teachers act as classroom facilitators rather than providers of standard answers. When students make analytical deviations or operational errors, teachers do not directly reject them but use more heuristic questions to guide students in independently organizing the diagnostic and treatment pro-

cess. After all practical exercises, common misconceptions are reviewed and explained collectively (Jiang et al., 2026; Wang & Sun, 2025).

3.2.3. Post-Class Consolidation and Extension

After class, students are not limited by laboratory space or opening hours. They can repeatedly log in to the virtual simulation platform, review the entire operational process of anatomy and surgery, and repeatedly practice weak areas. Assessment also forms a closed loop, including student self-reflection, peer evaluation within groups, and comprehensive teaching feedback from teachers based on platform operation trajectories, in-class discussion performance, and pre-class outputs.

3.3. Multi-Agent and Diversified Assessment System

Using Kirkpatrick's four-level evaluation model, this course constructs an assessment framework across four dimensions—reaction, learning, behavior, and results—and embeds multi-agent assessment into three types of assessment modules. Evaluation agents include teachers, group peers, and students themselves. Assessment modules are divided into formative, summative, and innovative categories, accounting for 50%, 30%, and 20%, respectively.

Formative assessment accounts for 50%, covering the reaction, learning, and behavior levels. The reaction level mainly evaluates students' satisfaction with the teaching model, participation experience, and learning motivation. Indicators include user experience of the virtual simulation platform, sense of participation in PBL group discussions, and satisfaction with classroom teamwork, assessed through student self-assessment and peer assessment. The learning level mainly evaluates knowledge acquisition and logical construction. Indicators include pre-class preparation, case reflection, and in-class case analysis, jointly assessed by teachers and peers. The behavior level mainly evaluates actual skill application and collaborative communication. Indicators include the quality of virtual simulation platform operations, contribution to PBL group discussions, and classroom teamwork performance, evaluated based on platform operation trajectories, teacher observation, and peer assessment.

Summative assessment accounts for 30%, covering the learning and behavior levels. The learning level uses mind-map drawing of the orthopedic knowledge system to evaluate students' mastery of the orthopedic knowledge framework, injury pathology, and diagnostic and treatment logic. The behavior level uses a virtual comprehensive case-management-based assessment to evaluate students' consultation, physical examination, image interpretation, diagnosis, and management abilities in virtual clinical scenarios.

Innovative assessment accounts for 20%, mainly corresponding to advanced behavior and providing programme-level evidence for the results level. It focuses on the optimized design of personalized diagnosis and treatment plans for fractures and joint diseases and on review and commentary of frontier orthopedic literature, examining students' critical thinking, literature analysis ability, and

comprehensive innovation ability. This forms an assessment system in which “reaction-learning-behavior-results” and “formative-summative-innovative” assessments are interconnected and progressively advanced.

Assessment Blueprint and Weighting Rationale

To render the multi-agent assessment system operable and traceable, this study develops the following assessment blueprint. Assessment is administered by three sets of assessors: teachers, peer group members, and students themselves. Evaluative evidence is drawn from a range of sources, including virtual simulation platform operation logs, PBL group discussion records, pre-class learning outputs, case analysis reports, mind maps, virtual comprehensive case management records, personalized diagnosis and treatment plans, and literature reviews. All scoring is conducted against predefined multi-dimensional rubrics, and mechanisms to safeguard individual accountability are integrated into the framework to ensure that individual contributions to group work are clearly identifiable and measurable (**Table 1**).

Table 1. Weighted assessment scheme for PBL and virtual simulation in undergraduate orthopedic teaching.

Assessment module (weight; Kirkpatrick level)	Assessor	Evidence source	Scoring rubric	Individual-accountability safeguard
Formative (50%; reaction/learning/behavior)	Teacher, peers, self	Platform logs, PBL discussion records, pre-class/reflection outputs, classroom performance	Participation, knowledge logic, operational standards, collaboration	One account per student, individual outputs scored separately, group role records archived, anomalous scores calibrated
Summative (30%; learning/behavior)	Teacher, platform auto-scoring	Orthopedic knowledge mind map, virtual comprehensive case management	Knowledge framework, diagnostic-treatment logic, clinical decision-making, operational standards	Independently completed, anonymous scoring, platform records, key decisions reviewed
Innovative (20%; advanced behavior; programme-level evidence for results)	Teacher, peers	Personalized diagnosis/treatment plan, frontier orthopedic literature review	Critical thinking, literature analysis, innovation and feasibility	Individual submission, peer assessment with written justification, final teacher judgment

Weighting rationale: Formative assessment makes up 50% of the total score. The core value of integrating PBL with virtual simulation lies in sustained active inquiry, repeated practice, and group collaboration, and formative assessment delivers timely feedback to drive deep student engagement. Summative assessment accounts for 30% and is designed to evaluate students’ mastery of the orthopedic knowledge system and their overall competency in virtual case management by the end of the course, serving as summative evidence for the learning and behavior dimensions. The remaining 20% is allocated to innovative assessment, which fos-

ters higher-order thinking, literature analysis skills, and the design of personalized diagnosis and treatment plans, providing preliminary programme-level evidence for the results dimension. The three groups of assessors—teachers, peers, and learners themselves—are deployed consistently across all modules: teacher assessment carries the most weight in summative and innovative components, while peer and self-assessment play a primary role in formative evaluation. Individual accountability mechanisms, unified scoring rubrics, and outlier score calibration ensure consistency across the three scoring streams and eliminate conflicting outcomes.

4. Practical Constraints on Implementation and Corresponding Optimization Strategies

Drawing on practical experience from similar teaching reforms in other disciplines in China, this model is logically complete at the theoretical level. However, when actually implemented in undergraduate classrooms, it is constrained by students' foundational knowledge, platform technology, teacher capacity, and resource development. The following sections review existing constraints and propose targeted optimization strategies.

4.1. Main Existing Constraints

Some students rarely use simulation software. At first, they may find the interface complex and operations cumbersome, spending energy familiarizing themselves with platform functions, which may distract them from core learning objectives. In addition, teaching in large classes is constrained by the number of computers in training laboratories and course scheduling (Jiang et al., 2026).

Under the PBL group collaboration model, if division of labor is unclear, a few students may take on the main thinking tasks while others participate passively without substantive engagement, leading to polarized learning outcomes among students (Fan & Song, 2025).

Instructors need not only solid clinical expertise in orthopedics but also the ability to organize and facilitate PBL classes, operate and debug virtual simulation platforms, and accurately identify the teaching points behind cases. If teachers have not received relevant pedagogical training, class discussions may drift off topic, and simulation teaching may become superficial (Sun et al., 2022).

High-quality three-dimensional anatomical models and highly realistic clinical teaching cases require long development cycles and high labor costs. Moreover, orthopedic clinical guidelines and diagnostic and treatment concepts are continuously updated, so the case library requires ongoing revision and updating.

4.2. Targeted Optimization Strategies

Brief, accessible introductory micro-lectures on platform operation should be created and distributed to students for preview before class. Layered and progressive learning tasks should be set: students with weaker foundations first complete sim-

plified anatomical identification exercises and gradually transition to complex surgical simulation operations. At the teaching management level, training laboratory scheduling resources should be coordinated to guarantee hardware conditions for classroom implementation.

Specific roles for each member in every group task should be clarified, and individual task outputs should be recorded. A dual-track feedback mechanism combining peer evaluation and teacher commentary should be implemented. Peer evaluation scores should be directly weighted into formative assessment grades to encourage every student to participate deeply in group learning.

Thematic teaching workshops should be organized on a regular basis, providing systematic training on PBL classroom organization, virtual simulation platform operation, and case-based teaching design. A working mechanism should be established in which frontline orthopedic clinicians participate in case development and refinement, ensuring that cases reflect real clinical scenarios.

A routine mechanism for revising and updating the case library should be established. Teaching resources should be continuously iterated according to updated clinical guidelines and real clinical cases.

5. Conclusion

For a long time, orthopedic teaching has faced multiple practical dilemmas, including abstract and difficult anatomy, insufficient practical training resources, a disconnect between theory and clinical practice, and a single assessment model. PBL drives students to actively inquire and think through real clinical problems. Virtual simulation technology, through digital means, transforms abstract anatomical structures, injury progression, and surgical procedures into immersive training scenarios. Their deep integration can effectively address many shortcomings of traditional orthopedic classrooms.

This paper draws on published teaching reform experience from physiology, dermatology, emergency medicine, and other disciplines and combines it with the teaching realities of local medical colleges to construct an integrated orthopedic teaching model of “tiered clinical case library, stratified virtual simulation training, multi-dimensional feedback-based assessment”. It establishes a complete pre-class, in-class, and post-class teaching loop and, based on an adapted Kirkpatrick’s four-level evaluation model, builds a trinity assessment system involving teacher assessment, peer assessment, and self-assessment. It reviews the practical constraints on implementation and provides actionable optimization measures. The teaching framework proposed in this study is conceptual by design, and its real-world educational efficacy remains to be verified through further empirical research.

The entire model adheres to a student-centered approach, shifting the teaching orientation from knowledge indoctrination to comprehensive competence development and strengthening students’ spatial anatomical cognition, surgical practical skills, and clinical decision-making thinking. It is hoped that this reform con-

cept can provide theoretical references and practical insights for the reform of orthopedic and surgery-related courses in local medical colleges.

Funding

2023 Guangxi Higher Education Undergraduate Teaching Reform Project (2023 JGA275). 2024 China University Industry-University-Research Innovation Fund—Special Project for Digital Empowerment of Education and Teaching (2024XL062).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- Fan, L. T., & Song, F. (2025). Exploration of the Application of AI in PBL Teaching of Basic Medical Sciences. *Basic Medical Education*, 27, 264-267. (In Chinese)
- Feng, L., Shi, L. X., Lü, J. Y., Wu, G. C., & Chen, J. Y. (2023). Exploration of the Combination of Virtual Simulation Experiments and PBL Teaching Method in Pathology. *Journal of North China University of Science and Technology (Health Sciences Edition)*, 25, 140-144. (In Chinese)
- Jiang, B. W., Guo, L. S., & Lin, F. X. (2026). Application of Virtual Simulation Technology Combined with PBL Teaching Method in Emergency Medicine Teaching. *Journal of Mudanjiang Medical University*, 47, 173-175+163. (In Chinese)
- Li, Y., & Gao, L. (2024). Application of Virtual Simulation Technology Combined with PBL Teaching Method in Standardized Resident Training of Echocardiography. *China Medical Education Technology*, 38, 107-111+117. (In Chinese)
- Liu, X., Lu, H. Q., Huang, L., Yin, G., Zhang, X. J., Jiang, N., & Wang, Y. (2024). Application of Virtual Simulation Situational Teaching Method Combined with PBL in Internal Medicine Teaching. *Clinical Journal of Traditional Chinese Medicine*, 36, 1415-1418. (In Chinese)
- Peng, W. S., Wang, L., Zhang, H., Zhang, Z., Wu, Y. M., Sang, X., & Chen, X. (2021). Application of Virtual Scenario Simulation Combined with Problem-Based Learning for Paediatric Medical Students. *Journal of International Medical Research*, 49, Article 0300060520979210. <https://doi.org/10.1177/0300060520979210>
- Roy, M., T. P., Ashika, M. S., Das, G., Patro, B. P., & Bharadwaj, S. (2025). Simulation-Based Learning in Orthopaedics: A Qualitative Systematic Review. *Journal of Clinical Orthopaedics and Trauma*, 65, Article 102986. <https://doi.org/10.1016/j.jcot.2025.102986>
- Song, Y. A., & Kim, M. (2023). Effects of a Virtual Reality Simulation Integrated with Problem-Based Learning on Nursing Students' Critical Thinking Ability, Problem Solving Ability, and Self-Efficacy: A Non-Randomized Trial. *Korean Journal of Women Health Nursing*, 29, 229-238. <https://doi.org/10.4069/kjwhn.2023.09.12>
- Sun, M. H., Di, X. W., Hao, C. Y., Li, S. Y., Li, D., Li, X. D., & Wang, L. L. (2022). Application of Virtual Simulation Technology Combined with PBL Teaching Method in Practical Teaching of Critical Care Nursing. *China Higher Medical Education*, 8, 121-122. (In Chinese)
- Wang, L. L., & Sun, J. (2025). Application of Virtual Simulation Technology Combined with Improved SPLICE Teaching Method in Clinical Practice Teaching of Dermatology.

China Medical Education Technology, 39, 126-131. (In Chinese)

- Wang, Y., Zhao, X. H., Zeng, J., Liu, J. X., Zhu, L., Wang, D. X., & Pan, T. (2022). Application of Virtual Reality Technology in the Teaching of Otolaryngology Anatomy for Eight-Year Program Medical Students. *Chinese Journal of Medical Education*, 42, 340-343. (In Chinese)
- Wei, K., & Wang, Y. (2025). Exploring the Impact of Combining PBL with Virtual Simulation Practical Training on Students' Learning Motivation. *Scientific Consultation*, 23, 141-144. (In Chinese)
- Xiong, X. H., Xu, J. N., Luo, M. Y., Niu, D. S., & Zhang, J. (2025). Efficacy of Problem-Based Learning Combined with Case-Based Learning versus Lecture-Based Learning in Orthopedic Education: A Systematic Review and Meta-Analysis. *BMC Medical Education*, 25, Article No. 1357. <https://doi.org/10.1186/s12909-025-07741-3>
- Xue, G., Zhang, X., Ji, S. Y., & Qi, J. (2026). Integrating Problem-Based Learning with Virtual Simulation in Trauma Orthopedic Education: Effects on Learning Outcomes and Student Satisfaction. *BMC Medical Education*, 26, Article No. 1240. <https://doi.org/10.1186/s12909-026-09558-0>
- Zheng, Y., Wang, J. H., Wang, L., Liang, Y. Q., Zhao, T. J., Yang, S. Q., & Xiao, H. Y. (2026). Exploration and Reform of the Implementation of PBL Combined with Virtual Simulation Technology in Physiology Courses. *Journal of Traditional Chinese Medicine Management*, 34, 14-17. (In Chinese)