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# Exploration of the Teaching Path of CBL Combined with PBL in Enhancing the Clinical Decision-Making Ability of Medical Imaging Technology Trainees

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## Abstract

The traditional medical imaging technology training model is difficult to meet the demand for cultivating high-level talents with clinical thinking, technical decision-making, and complex problem-solving abilities. This study aims to explore the application value of the combined model of case-based learning (CBL) and problem-based learning (PBL) in the training of medical imaging technology trainees. This article is positioned in the field of teaching design research, aiming to construct a theory-driven teaching model rather than reporting the effect evaluation of an implemented intervention. Through theoretical analysis and model construction, the "CBL-PBL Dual-Drive" teaching model is proposed. This model takes real cases as the situational anchor and key technical problems as the driving force for exploration, promoting learning in a cyclical manner. The study first clarifies the four core dimensions of "clinical decision-making ability" for medical imaging technology trainees: technical priority decision-making, parameterization of scanning protocols, image quality risk management, and team safety communication, and takes them as the core goals and assessment anchors throughout the teaching design. By combining specific teaching cases, the article demonstrates its application value from four dimensions: knowledge integration, ability advancement, professional ethics, and mutual growth in teaching and learning, and objectively analyzes the challenges and countermeasures in terms of teachers, resources, and evaluation. The study suggests that the CBL-PBL model can effectively promote the deep integration of knowledge, ability, and quality, providing an

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operational innovative path for cultivating high-quality, compound medical imaging technology talents and offering important references for promoting the reform of professional continuing education.

**Keywords**

Medical Imaging Technology, Continuing Education, CBL, PBL, Clinical Decision-Making Ability, Teaching Reform

## 1. Introduction

Medical imaging technology has entered a stage of rapid development led by artificial intelligence and multimodal fusion, profoundly reconstructing the clinical diagnosis and treatment process (Yu et al., 2025). The role of imaging technicians is transforming from "equipment operators" to "clinical technical partners", urgently requiring the ability to make technical decisions based on clinical problems, optimize scanning protocols, and practice evidence-based medicine (Hong et al., 2026). However, the current continuing education mainly relies on the "master-apprentice" or on-the-job training model, which has shortcomings such as lagging knowledge updates and insufficient cultivation of critical thinking, making it difficult to support the construction of a new ability system. There is a common dilemma of "disconnection between knowledge and practice": practice often remains at the level of observation, and theory is usually unidirectionally imparted, failing to effectively cultivate trainees' abilities for in-depth analysis, independent decision-making, and innovation (Liu et al., 2025).

Problem-based learning and case-based learning, as active learning paradigms, offer possibilities to address these challenges. PBL drives self-directed exploration through open-ended problems, fostering problem-solving and lifelong learning skills; CBL, based on real cases, promotes knowledge integration and clinical decision-making thinking (Zhou et al., 2025; Ren et al., 2025; Ge et al., 2025).

International medical education research has confirmed that PBL has a significant advantage in cultivating clinical reasoning ability, while CBL can more efficiently promote the transfer and application of knowledge in typical scenarios (McLean, 2023; Zhao et al., 2020). The integrated application of the two shows a synergistic effect in the cultivation of high-level clinical thinking ability (Daniel et al., 2022).

However, existing research mainly focuses on clinical medicine and imaging diagnosis education, emphasizing the cultivation of disease diagnosis thinking. For the medical imaging technology profession, whose core task is to "generate and optimize imaging data that meet diagnostic needs", especially for trainees who need to break through technical bottlenecks, there is a lack of systematic exploration on how to organically integrate CBL and PBL. For instance, how to design teaching cases that focus on technical characteristics (such as personalized protocol customization, image quality control, radiation safety, and contrast agent ethics), how to construct a complete teaching loop from clinical needs to the evaluation of technical solution implementation, and how to scientifically evaluate the long-term impact of this model on trainees' core technical abilities, all remain to be explored in depth.

Therefore, this study precisely focuses on medical imaging technology trainees and explores the deep integration model of CBL and PBL. Unlike diagnostic education, which emphasizes "image interpretation", this study focuses on trainees' "technical decision-making" and "solution optimization" abilities in specific clinical needs. Through theory-driven model development and standardized case design, the aim is to form a set of highly professional and operational integrated teaching plans, providing innovative ideas and practical references for the cultivation of high-level applied talents in medical imaging technology, and contributing to the high-quality development of medical care.

## 2. Core Concepts and Theoretical Foundations

### 2.1. Analysis of the Learning Characteristics of Medical Imaging Technology Trainees

Medical imaging technology trainees, as typical adult learners and practitioners (Tao & Xu, 2024), have distinct characteristics: First, they have clear learning goals and a strong practical orientation, often participating in training with specific clinical problems in mind and seeking directly applicable solutions. Second, their experience base is dual: they have valuable practical experience as a learning scaffold, but may also have ingrained habits or partial understandings that need to be examined and updated. Third, they have strong self-directed learning abilities, but require appropriate teaching contexts and guidance strategies to stimulate their exploration potential. Fourth, they emphasize learning efficiency and returns, expecting to maximize their professional capabilities within a limited time. Therefore, an ideal teaching model must effectively activate their prior experiences, create challenging real-world tasks, promote deep reflection, and support them in reconstructing knowledge meaningfully through collaboration.

### 2.2. The Essence of CBL and PBL and Their Specificity in Medical Imaging Technology Teaching

The core of CBL lies in "context" and "integration". It uses a complete real clinical case as the learning center and context anchor. In medical imaging technology teaching, a high-quality CBL case not only includes patient information and diagnosis but also highlights the key intervention points for technicians, such as specific scanning parameters, image post-processing procedures, and final quality assessment. Its goal is to construct a complete closed loop of "clinical need - technical execution - image result", prompting trainees to comprehensively apply knowledge in specific contexts and complete systematic thinking training from need analysis to technical execution and optimization. Its advantage lies in its focused goal and realistic context, effectively promoting the integration and application of knowledge.

The core of PBL lies in "problems" and "process". It starts with an open, unstructured clinical technology problem as the learning point and continuous driving force. The problem directly points to the core of "how to obtain the best images to meet specific diagnostic needs". Trainees independently identify learning needs, collect information, analyze, and solve problems in groups. PBL focuses on the exploration process itself, aiming to stimulate intrinsic motivation and systematically cultivate trainees' autonomous exploration, critical thinking, and teamwork skills, shaping their problem-solving abilities throughout the process.

### 2.3. The Integration of CBL and PBL: Theoretical Necessity and Synergistic Effects

The combination with PBL forms a powerful teaching paradigm with complementary advantages. CBL provides "structure" and "focus" for PBL. It uses real cases as specific, bounded learning contexts, building a clearly targeted "battlefield" for potentially divergent exploration activities in PBL, ensuring the depth and clinical relevance of learning. Conversely, PBL injects "motivation" and "depth" into CBL. Through carefully designed problem chains, it drives trainees to actively explore the technical principles, solution disputes, and evidence-based grounds behind cases, transforming the information reception in CBL into an active knowledge construction process.

The essence of this integration is the organic fusion of "situational cognition" and "constructivism" theories. CBL creates a realistic "community of practice" context, allowing trainees to participate as "preliminary experts"; PBL, driven by problems, supports trainees in actively "negotiating meaning" in this context, facilitating their critical identity transformation from "skilled operators" to "reflective practitioners" and "technical decision-makers".

### 2.4. Model Development Methodology

To ensure the theoretical rigor and practical applicability of the teaching model, this study follows the following development process: Firstly, the literature review method is adopted to systematically sort out the application framework of CBL/PBL integrated teaching in health professional education and extract key design principles. Secondly, through the task analysis method, semi-structured interviews are conducted with five senior imaging technology supervisors and three radiology department directors to summarize the core behavioral manifestations of clinical decision-making ability of trainees. Thirdly, based on the first stage (Analysis) of the ADDIE instructional design model, a theoretical prototype of "CBL-PBL dual-wheel drive" is constructed. At the case development level, all teaching examples are sourced from the PACS system of our hospital. The selection criteria are: 1) covering common diseases and critical and severe conditions; 2) including clear technical controversy points or optimization space; 3) having complete imaging chain data. The cases are reviewed and standardized by three senior imaging technicians with advanced professional titles and one medical education expert in a dual-wheel process to ensure their teaching relevance and professionalism.

# 3. Construction and Implementation of the "CBL-PBL Dual-Drive" Teaching Model

## 3.1. The Logic and Overall Framework of Model Construction

Based on the above theoretical analysis, an integrated "CBL-PBL Dual-Drive" model suitable for medical imaging technology refresher teaching is constructed. Its core logic is: "Taking cases as the guideline, creating real learning scenarios; using problems as the lead, driving the active exploration process; dual-wheel interaction, achieving the unity of knowledge and action." The model emphasizes the cyclical interaction and mutual reinforcement of CBL and PBL in the teaching process, jointly promoting the in-depth development of learning. The overall framework of the model and its four progressive stages are shown in Figure 1.

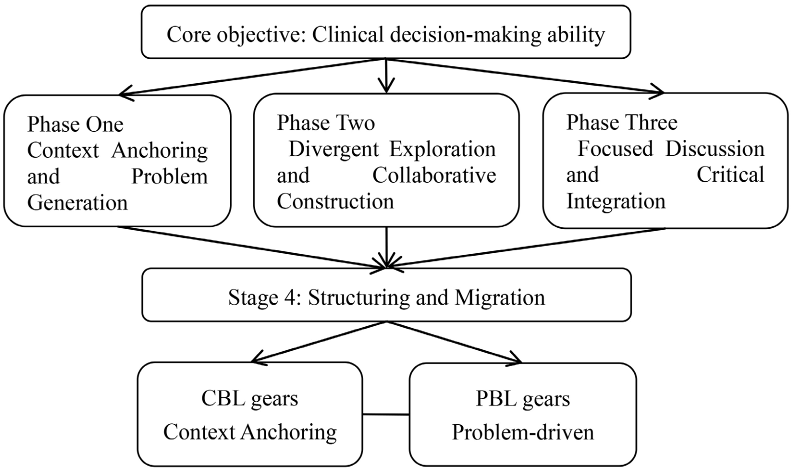

Figure 1. The CBL-PBL dual-driven teaching model.

## 3.2. Detailed Explanation of the Implementation Stages of the Teaching Model

### 3.2.1. Stage One: Context Anchoring and Problem Generation (CBL-Led)

The teacher presents a real or standardized case with teaching value, such as: "A 65-year-old male, sudden severe chest pain with tearing back pain, blood pressure 180/110 mmHg, heart rate 110 beats per minute, significantly elevated D-dimer", and provides initial information such as an electrocardiogram, chest X-ray, and clinical application form. Then, the teacher poses a series of core driving questions to guide the trainees to focus on technical decisions: [Technical Decision] "As the receiving technician, based on the current information, what do you think is the most prioritized imaging examination (such as CTPA, aortic CTA, coronary CTA)? Please rank the priorities and explain the decision-making basis, referring to relevant clinical guidelines." [Plan Optimization] "If there is a high clinical suspicion of aortic dissection, please design a personalized scanning and post-processing plan for this patient's thoracoabdominal aortic CTA as a group. It should cover contrast agent flow rate and dosage, scanning phase, radiation dose optimization strategy, and contingency plans for potential artifacts." [Safety and Communication] "What key communications do you need to have with the patient, emergency doctor, and nurse before, during, and after the examination? Please identify the main risks during the examination (such as contrast agent extravasation, allergic reactions, blood pressure fluctuations) and formulate emergency plans."

### 3.2.2. Stage Two: Divergent Exploration and Collaborative Construction (PBL-Led)

The trainees work in groups (3 - 5 people) to independently explore the driving questions. They need to divide the work, consult textbooks, professional guidelines, and the latest literature, review similar cases in the PACS system for image analysis, and can simulate or actually consult radiologists and clinical doctors. During this process, the teacher's role changes to "facilitator" and "resource advisor", guiding the exploration direction by observing and asking metacognitive questions (such as "What is the basis of your judgment?" "Are there any other possibilities?") instead of directly providing answers. Each group must eventually form a preliminary report including the reasons for technical decisions, detailed scanning plans, and key communication points.

### 3.2.3. Stage Three: Focused Discussion and Critical Integration (Deep Integration of CBL and PBL)

This stage is the key integration phase of teaching: Each group first reports their exploration results, and then the teacher gradually reveals the complete subsequent information of the case (such as actual CTA images, which not only show typical aortic dissection but also present motion artifacts due to patient restlessness), bringing the classroom discussion to a climax. The teacher deepens learning through two levels: on the one hand, guiding critical image-based analysis, organizing all trainees to compare and debate the technical plans and final image quality of each group (such as discussing "Does the low tube voltage plan adopted by Group A achieve the best balance between image noise and contrast? Is it applicable to obese patients?" or "The feasibility and pros and cons of Group B's electrocardiogram gating technique in the emergency setting?"); On the other hand, gradually increase the complexity of the scenarios (such as posing questions like "If the patient's serum creatinine level rises, how should the contrast agent protocol be adjusted?" or "What is the application value and limitation of AI-assisted vascular analysis software in this case?"). This process places the previously scattered knowledge to the test of real case outcomes, subjecting it to verification, criticism and reconstruction, ultimately promoting the formation of a multi-dimensional and in-depth understanding of complex clinical technical issues among trainees.

#### 3.2.4. Stage Four: Structuring and Transfer Expansion (CBL Return)

The instructor systematically reviews the value of the entire imaging examination in the entire diagnosis and treatment chain, and conducts a structured knowledge review, integrating the case knowledge points into a systematic knowledge map (such as the "Imaging Technology Decision Pathway Map for Acute Chest Pain Triad"). Finally, the instructor conducts a transfer training, providing a new case that is similar but has key differences (such as "Designing an Imaging Examination Plan for a Pregnant Woman Suspected of Pulmonary Embolism"), requiring trainees to independently analyze it after class, achieving effective positive transfer of learning outcomes to new situations.

### 3.3. Teaching Case Design Example: Taking "Acute Ischemic Stroke" as an Example

This case is based on a 68-year-old female (admitted to the hospital with sudden right limb weakness and slurred speech for 2 hours, NIHSS score of 12 points), setting a driving question: As a technician, how to activate the "Stroke Imaging Rapid Response Channel"? Please design a one-stop scanning plan for multi-mode CT (NCCT + CTP + CTA), and explain the purpose, key parameters and dose control strategies of each sequence; explain the key parameter maps and technical guarantee points for judging the ischemic penumbra in CTP post-processing; and design a multi-mode MRI plan, and compare the advantages and disadvantages and applicable scenarios of CT and MRI technology paths. Through exploration, trainees need to ultimately form a "Standardized Process Suggestion for Acute Stroke Imaging Technology Assessment", and discuss emergency optimization plans in cases of equipment or time constraints.

### 3.4. Design of the Teaching Evaluation Blueprint

To systematically assess the achievement of trainees' clinical decision-making abilities, this study has developed a diversified evaluation blueprint that precisely aligns with the teaching phases: In phases one and two, the personalized scanning protocol sheets and technical decision-making basis reports submitted by trainees will be independently evaluated by two teaching instructors based on the protocol rationality scoring table and clinical reasoning scoring scale, and the inter-rater reliability will be tested to ensure consistency. In phase three, the analysis and optimization plans written by trainees for real image artifacts will be scored by teaching instructors and peer-reviewed among groups, focusing on problem attribution and innovative strategies. In phase four and throughout the entire teaching process, the patient safety check communication lists formulated by trainees will be evaluated for communication skills by standardized patients or instructors through objective structured assessment forms, while personal reflection logs will be analyzed using thematic analysis to examine the development of metacognition and professional identity. This evaluation blueprint adheres to the principles of standard openness, process transparency, and multi-source feedback, aiming to achieve a comprehensive and formative evaluation of the four core ability dimensions of technical priority decision-making, scanning protocol parameterization, image quality risk management, and team safety communication through a combination of multiple tasks, tools, and evaluators.

### 3.5. Ethical and Governance Statement

All clinical cases used for teaching in this study were sourced from a teaching case resource library that has been exempted from review by the hospital's ethics committee. All image data were strictly de-identified before being entered into the database, with all personally identifiable information such as patient names, hospital numbers, and facial features removed. The use of cases was authorized by the hospital's Medical Imaging Department Teaching Resources Management Committee. During the teaching process, discussions on radiation dose optimization and the safe application of contrast agents strictly adhered to the "Principle of Optimization of Radiation Protection" and the "European Society of Urogenital Radiology Contrast Agent Guidelines", guiding students to prioritize patient safety in technical decision-making. In the simulation exercises, the basis for dose decisions and emergency plans for adverse reactions were recorded as an important part of the formative assessment.

## 4. Multi-Dimensional Analysis of Application Value

### 4.1. Knowledge Dimension: From Fragmentation to Integration, Building a "Living" Knowledge System

The joint model compels trainees to actively link fragmented knowledge such as anatomy, pathology, physics, engineering, and ethics around real cases into an organic whole that serves to "solve technical problems". This knowledge, constructed based on demand and application, is a "living knowledge" that is deeply understood and easily transferable.

### 4.2. Competency Dimension: From Operation to Decision-Making, Cultivating High-Level Professional Competencies

This teaching model systematically enhances four core competencies of trainees: In terms of clinical thinking and technical decision-making, trainees transform from passive executors to active "technical detectives", capable of analyzing clinical information, weighing risks and benefits, and making evidence-based optimal technical choices; in terms of complex problem-solving, through dealing with real non-standardized challenges such as image artifacts and low patient cooperation, a complete ability chain from problem analysis, solution exploration to innovative optimization is systematically trained; in terms of self-directed learning and lifelong learning, through the cycle of "encountering problems—seeking resources—solving problems", they master the core methods for continuous self-updating in the context of rapid technological iteration; in terms of communication and teamwork, through group collaboration and role-playing, they repeatedly practice effective communication with clinical teams, patients, and their families, cultivating the non-technical professional qualities necessary as “clinical technology partners”.

### 4.3. Quality Dimension: From Technology to Humanity, Shaping Comprehensive Professional Spirit

In the quality dimension, this teaching model promotes the transformation of trainees from pure technical operators to professionals with comprehensive professional spirit: Through in-depth discussions on topics such as radiation dose optimization, safe application of contrast agents, and handling of critical values, patient safety awareness and medical ethics are naturally internalized, deepening the professional belief of “patient-centeredness”; at the same time, through repeated critical reviews of image quality and continuous discussions on technical solutions, the awareness of continuous quality improvement in pursuit of excellence and perfection is systematically implanted, shaping their profound professional spirit genes.

### 4.4. Teaching and Learning Mutual Enhancement Dimension: Promoting the Level of the Teaching Staff

The implementation of this model poses all-round challenges to teachers, forcing them to update their knowledge and enhance their abilities in case design and classroom guidance. At the same time, teachers can draw diverse practical experiences from trainees from different hospitals, achieving true teaching and learning mutual enhancement.

## 5. Discussion

The “CBL-PBL Dual-Drive” teaching model constructed in this study has its core value in precisely responding to the talent capability transformation demand in the medical imaging technology field from “operation execution” to “clinical decision-making”. This model, through the organic integration of CBL creating real scenarios and PBL driving in-depth exploration, builds a highly simulated and challenging “pre-expert” practice field. In this field, trainees not only complete the systematic integration of interdisciplinary knowledge but more importantly, achieve a fundamental transformation of their professional identity—from passive operators following instructions to active technical partners who can independently analyze clinical needs, make evidence-based decisions, optimize plans, and take on communication and coordination responsibilities. This study deconstructed the abstract “clinical decision-making ability” into four measurable and teachable specific dimensions, and designed precise teaching activities and assessment tools to match them, providing a highly operational theoretical implementation framework for the field of imaging technology education. This teaching loop centered on real cases and linked by complex problems effectively bridges the gap between “knowledge” and “practice” in traditional training, providing an innovative and practical path for cultivating high-quality, compound imaging technology talents that can adapt to the high-quality development of medical care. This model is not only applicable to advanced studies but also offers a practical model for high-level ability cultivation in educational institutions and business learning in clinical departments.

Any teaching reform from theoretical construction to practical implementation faces real challenges, and this model is no exception. The primary challenge lies in the extremely high requirement for the compound capabilities of teachers, who need to possess profound knowledge in imaging technology, rich clinical experience, and proficient PBL guidance and classroom management skills. Secondly, the construction and maintenance of a high-quality, systematic digital teaching resource library (such as standardized cases, problem sets, and imaging data sets) is a long-term and arduous task. Furthermore, within the limited advanced study period, balancing the depth of inquiry learning with the breadth of knowledge coverage is a practical test of teaching design art. Finally, the traditional evaluation system based on knowledge memorization cannot effectively measure the growth of trainees in clinical thinking, decision-making processes, and communication and collaboration, and thus requires reform. The assessment blueprint proposed in this study, although striving for systematicity, still requires further validation and iterative optimization in large-scale teaching practices in terms of its reliability and validity.

In response to these challenges, this study proposes systematic countermeasures: at the teacher level, form a "structured teaching team" composed of imaging technicians, physicians, and physicists to achieve complementary advantages. In terms of resource construction, promote regional collaborative construction and sharing, develop modular resource packages, and utilize virtual simulation technology. In teaching organization, adopt a blended online and offline model, with self-study of basic theories online and face-to-face teaching focusing on high-level discussions. In the evaluation system, construct a diversified process-oriented evaluation system based on capabilities, comprehensively applying project assessment, reflection reports, oral defense, and multi-station objective structured clinical examinations. We will continue to promote a diversified process-oriented evaluation based on capabilities, and comprehensively apply project assessment, reflective reports, oral defense, and multi-station objective structured examinations.

Looking to the future, it is necessary to develop refined course modules for subspecialties and actively explore the integration with cutting-edge technologies such as artificial intelligence to build intelligent teaching systems and cultivate students' data thinking. As a teaching design research, the inevitable path for the next stage of this study is to shift towards empirical effect evaluation. The subsequent research plan is to adopt a quasi-experimental design, set up a control group, and use the evaluation blueprint developed in this paper, combined with standardized patient tests, job performance tracking, and 360-degree evaluations, to multi-dimensionally verify the long-term impact of this model on students' clinical decision-making ability, job competence, and patient safety culture. Ultimately, through continuous iteration, this model will become the core engine driving lifelong learning for professional talents and contribute to the improvement of medical service quality.

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## Conflicts of Interest

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

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