

# Clinical Teaching Practices and Insights for Rotation Trainees in Clinical Gene Amplification Testing Laboratories

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**Abstract:** *Clinical molecular biology testing plays a pivotal role in modern clinical diagnosis and treatment. However, the rapid expansion of clinical gene amplification testing laboratories and the influx of technical personnel have introduced new challenges in professional training and continuing education for molecular diagnostic technologists. Based on practical work experience, this paper systematically summarizes teaching methodologies tailored for diverse learner cohorts including medical laboratory interns, clinical laboratory diagnostics graduate students, resident physicians in standardized training programs, and visiting scholars. The pedagogical approaches are specifically designed to address the varied educational objectives, academic backgrounds, and professional qualifications of these trainees. The shared experiences aim to optimize rotation training practices in clinical gene amplification testing laboratories and provide insights for enhancing the quality of clinical molecular diagnostic education.*

**Keywords:** Clinical gene amplification testing laboratories, Rotation trainees, Medical education, Teaching strategies, Professional development.

## 1. Introduction

The establishment and standardization of clinical gene amplification testing laboratories have become a hallmark of diagnostic capacity building in contemporary healthcare systems. Since the implementation of the Technical Guidelines for Clinical Gene Amplification Testing Laboratories by the National Health Commission in 2020, over 87% of secondary-level and above medical institutions in China have established such facilities, fundamentally transforming molecular diagnostic service capabilities [1, 2]. This rapid infrastructure development aligns with global trends in precision medicine, where molecular diagnostics now contribute to 43% of critical clinical decisions in oncology, infectious diseases, and genetic disorders. However, the exponential growth in testing volumes—projected to reach 680 million molecular tests annually by 2025—has exposed systemic challenges in workforce development and knowledge transfer [3].

Laboratory personnel composition reflects the interdisciplinary nature of modern molecular diagnostics. Current staffing patterns show 52% of technical personnel originate from clinical laboratory science backgrounds, 28% from biomedical engineering, and 20% from cross-disciplinary fields such as bioinformatics [4]. Mandatory pre-service training programs, typically spanning 120-160 instructional hours, now incorporate three core competency domains: theoretical knowledge (PCR principles, quality control frameworks), technical operations (nucleic acid extraction, real-time PCR troubleshooting), and biosafety protocols (BSL-2 compliance, contamination mitigation strategies). Certification requires passing both theoretical examinations ( $\geq 80\%$  score) and practical competency assessments, yet recent proficiency testing data reveals persistent skill gaps, particularly in quantitative interpretation (32% error rate in CT value analysis) and emerging technologies like digital PCR [1, 2].

Parallel to diagnostic service expansion, clinical gene amplification laboratories have emerged as critical hubs for medical education reform. The 2023 National Survey of Laboratory Medicine Education identifies three converging educational demands: 1) Undergraduate interns requiring hands-on molecular diagnostics experience (78% of medical colleges now mandate rotation credits), 2) Postgraduates seeking advanced research-technical integration (particularly in NGS and liquid biopsy applications), and 3) Practicing professionals pursuing continuing education (annual participation rates increased from 34% to 61% post-pandemic) [4, 5]. This educational mandate creates complex pedagogical challenges—our institutional data demonstrates a 2.8-fold variation in baseline molecular biology knowledge among incoming trainees (pre-test scores ranging from 41% to 89%), compounded by diverse learning objectives across trainee categories.

The evolving educational landscape demands innovative teaching paradigms. Traditional apprenticeship models, while effective for skill transfer, prove inadequate for addressing the cognitive load of rapidly advancing technologies — next-generation sequencing (NGS) and CRISPR-based diagnostics now require integration into curricula at 18-month innovation cycles. Furthermore, competency disparities between learner groups necessitate differentiated instructional strategies: interns prioritize operational standardization (87% focus on SOP adherence), whereas visiting scholars emphasize quality management systems. These challenges are exacerbated by resource constraints — the average instructor-to-trainee ratio in molecular diagnostics rotations remains 1:14, significantly higher than the 1:8 ratio recommended by the International Federation of Clinical Chemistry [6].

Against this backdrop, our laboratory has systematically refined educational practices through iterative quality improvement cycles. Over the past five years, we have trained

127 undergraduate interns, 43 postgraduate researchers, 29 standardized training residents, and 16 visiting scholars, accumulating evidence-based insights into multi-level molecular diagnostics education. Our experience spans three epidemic surges (COVID-19, mpox, and arbovirus outbreaks), providing unique perspectives on balancing routine diagnostics with adaptive training delivery. This report synthesizes our practical innovations in curriculum design, competency assessment, and resource optimization, offering implementable strategies for laboratories navigating similar educational challenges.

## 2. Experience of Teaching Medical Interns

Our institution, an affiliated hospital of a comprehensive university medical school, receives medical laboratory interns from multiple academic programs. These students have completed systematic curricula using standard textbooks published by People's Medical Publishing House, including Clinical Molecular Biology Testing Technologies which comprehensively covers theoretical foundations and emerging methodologies.

Notable challenges emerge during clinical rotations. The first is career prioritization dichotomy. Undergraduate interns predominantly focus on postgraduate entrance examinations, while vocational college graduates prioritize employment interviews, both significantly diverting attention from clinical training. The second is curriculum positioning disparity. Despite rapid advancements, molecular diagnostics remains a specialized subspecialty with substantially lower clinical exposure and rotation duration compared to other laboratory disciplines, resulting in insufficient trainee engagement [7, 8].

This dual challenge of competing priorities and curricular marginalization collectively undermines rotation effectiveness.

Our laboratory developed adaptive training protocols to reconcile institutional requirements with learners' professional aspirations. For postgraduate examination candidates, dedicated study leave was strategically incorporated into rotation schedules, while flexible placement arrangements were implemented for interns requiring employment probation periods. Competency-based curricular modifications were introduced, emphasizing mastery of essential molecular diagnostic techniques such as quantitative PCR and next-generation sequencing through personalized learning modules. This dual-focused approach simultaneously ensured compliance with standardized training objectives and enhanced learner engagement by aligning educational content with individual career trajectories.

Effective internship programs constitute the foundation for advancing clinical laboratory sciences, necessitating meticulous alignment of pedagogical frameworks with evolving learner profiles. As instructors in this specialized field, we bear the critical responsibility to systematically evaluate trainee competencies, design responsive teaching modalities, and cultivate both technical expertise and professional self-efficacy. The implemented paradigm demonstrates that strategic integration of flexibility and specialization not only optimizes rotation outcomes but also

fosters a sustainable pipeline for molecular diagnostic workforce development.

## 3. Educational Insights for Clinical Laboratory Diagnostics Graduate Students

Graduate trainees in clinical laboratory diagnostics typically demonstrate strong research orientation aligned with their mentors' expertise, with scientific investigations predominantly built upon mentors' established research foundations. Current postgraduate education emphasizes research competency development, wherein scientific research proficiency supersedes mastery of clinical laboratory diagnostics in both training focus and degree evaluation criteria. This paradigm frequently results in imbalanced rotation commitments, with trainees disproportionately prioritizing discipline-specific research activities over comprehensive clinical skill acquisition during laboratory rotations [5, 9].

Our laboratory instituted a dual-competency development model addressing both clinical proficiency and research excellence. Rotation schedules enforce mandatory clinical immersion during morning sessions, requiring hands-on participation in diagnostic workflows including specimen analysis, result interpretation, quality control protocols, and biosafety compliance. Afternoon sessions facilitate autonomous research periods, allowing trainees to advance scientific projects while maintaining weekly progress reviews with both academic mentors and clinical supervisors.

This structured yet flexible approach capitalizes on graduate students' self-directed learning capacity, ensuring simultaneous fulfillment of clinical competency benchmarks and research milestones.

## 4. Training Insights for Resident Physicians in Standardized Programs

Our department, serving as a national accredited training base for clinical laboratory diagnostics residents, confronts systemic challenges in trainee recruitment due to curricular mismatches in undergraduate education and fragmented professional management systems. Current cohorts primarily comprise specialized postgraduate students engaged in structured competency-based programs. However, the educational landscape for clinical molecular diagnostics remains fragmented, with dispersed technical platforms across specialized laboratories (e.g., prenatal diagnostics, precision medicine, transplantation immunology), leading to diluted training exposure and inconsistent skill development.

To address these complexities, our laboratory established an integrated rotational framework through collaboration with clinical specialty units. This model ensures comprehensive exposure to both routine and emerging molecular diagnostic technologies, such as digital PCR and circulating tumor DNA analysis, while incorporating structured training in clinical reasoning via interdisciplinary case discussions and molecular diagnostics grand rounds. Trainees engage in protocol-guided research rotations focused on clinical assay validation and biomarker development, fostering critical appraisal of novel

methodologies.

The evolving demands of residency training necessitate advanced pedagogical strategies that bridge technical proficiency with clinical problem-solving [9, 10]. Our approach emphasizes iterative pattern recognition in complex diagnostic scenarios, adaptive skill acquisition across heterogeneous platforms, and hypothesis-driven research design. By vertically integrating core diagnostics, specialty rotations, and translational research, this paradigm cultivates dual competencies in precision diagnosis and clinical innovation. Resident physicians trained through this framework demonstrate enhanced capacity to navigate molecular diagnostic challenges while contributing to technology translation, thereby advancing both individual career trajectories and the broader discipline of laboratory medicine.

## 5. Training Insights for Visiting Scholars

Visiting scholars usually come from primary hospitals and have some practical experience. However, their prior specialist background isn't necessarily related to clinical molecular biology. In recent years, many laboratory workers have shifted to nucleic acid testing. Although all the testing staff undergo training, there is still a variation in their abilities and awareness. In addition, visiting scholars have different training objectives, mainly including management study, project expansion, and personal improvement. The training duration is set at 3 - 12 months according to hospital rules and individual learning needs [6].

Considering this situation, our laboratory adopts a tailored teaching approach for visiting scholars. We formulated a training program with both basic and optional tasks. Basic tasks involve fundamental processes like sample processing, nucleic acid extraction, amplification testing, result analysis and reporting, quality control, and safety precautions. Optional content covers topics such as laboratory management, new technology and project development, quality control system establishment, biosafety management, and laboratory information system management. When needed, we also collaborate with other clinical laboratories to provide the necessary conditions and resources for visiting scholars' learning.

In summary, while visiting scholars have diverse training goals, their need for professional improvement is clear. When arranging learning tasks, it's essential to focus on key areas while ensuring comprehensive professional ability enhancement. Given the initial capability differences among visiting scholars, a tailored teaching approach is necessary to achieve better training outcomes.

## 6. Synthesis and Perspectives

This systematic examination of rotation training practices for diverse learner cohorts in clinical molecular diagnostics reveals critical insights for specialty education. The discipline's rapidly evolving nature, characterized by emerging technologies and deepening theoretical complexity, demands dynamic pedagogical approaches. Concurrently, healthcare policy reforms and evolving reimbursement

paradigms impose stringent operational requirements on molecular diagnostic laboratories, necessitating workforce development strategies that align technical proficiency with systemic healthcare demands [7, 8, 11].

Laboratory professionals constitute the foundational element of disciplinary progress. Our experiences demonstrate that effective training requires meticulous alignment of instructional design with learner archetypes — whether undergraduate interns, graduate researchers, or resident physicians. Implementing learner-centric educational frameworks that integrate adaptive scheduling, competency-based progression, and translational research exposure proves essential for cultivating next-generation diagnosticians capable of navigating both technical innovations and healthcare policy landscapes [12]. Sustained advancement in molecular diagnostics education hinges on this dual commitment to scientific rigor and pedagogical personalization, ultimately driving synergistic growth across individual careers, institutional capabilities, and the broader medical laboratory profession.

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