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Design and Implementation of an Integrated Teaching Approach for Transmission Electron Microscopy Laboratory Education

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Abstract
This study explored the use of transmission electron microscopy (TEM) in undergraduate and postgraduate biology laboratory teaching and research training. Traditional TEM courses had limited experiments, rigid teaching methods, and weak links to current research. To address this, instructional content was improved, teaching methods diversified, research activities included, and assessments updated. Students completed the full TEM workflow, including sample preparation, instrument operation, imaging, and data analysis. This hands-on experience strengthened understanding of TEM principles, practical skills, and data interpretation. After the reform, students showed higher motivation, deeper comprehension, and better performance. The findings indicate that a structured TEM curriculum with integrated research activities enhances experimental competence and supports the development of research-focused biological talent. This approach provides a practical model for high-quality laboratory education.

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1. Introduction

In biology laboratory education, observing cells and their ultrastructures is crucial for understanding the fundamental composition of life and the hierarchical organization of tissues. Combining theoretical instruction with direct observation of biological structures helps students grasp structure–function relationships and lays a foundation for subsequent studies on functional mechanisms and applied research. Currently, optical microscopy is the most commonly used tool in undergraduate biology laboratories. While sufficient for identifying cells and tissues, its resolution is limited by diffraction and imaging conditions, making it difficult to clearly visualize subcellular structures such as mitochondrial cristae, endoplasmic reticulum, and ribosomes. Auto fluorescence and low contrast further compromise image quality, restricting students' comprehension of ultrastructural hierarchies.

Transmission electron microscopy (TEM) employs high-energy electron beams to examine samples and reveal cellular ultrastructure at the nanometer scale. TEM has been widely applied in life sciences research. In laboratory teaching, integrating TEM theory with practical training allows students to directly observe fine cellular structures, strengthen their understanding of imaging principles, and develop research skills. However, TEM instruments are complex, expensive to operate, and require substantial maintenance. Many universities face resource limitations, which creates tension between teaching and research demands [1-3]. Enhancing TEM utilization under these constraints and effectively combining teaching with research training remain significant challenges.

In this study, the JEM-2100 TEM at the Agricultural Bioengineering Research Institute of Guizhou university served as a case study. By identifying current challenges in TEM education and implementing practical instructional reforms, this work provides guidance for the effective integration of TEM into biology laboratory teaching.

2. Current Status of TEM Laboratory Teaching

2.1. Limited Teaching Modes and Student Engagement

The TEM courses at the School of Life Sciences are primarily designed for undergraduate and graduate biology students. Although students have completed prerequisite courses such as Instrumental Analysis and possess basic theoretical knowledge, their practical skills and standardized operational experience remain limited. The curriculum requires students to understand TEM principles, operational procedures, and maintenance, and to acquire basic independent operation ability. However, due to the complexity and enclosed nature of the instrument, students' understanding of internal mechanisms is largely conceptual, resulting in insufficient integration of theory and practice.

Biological sample preparation is complex and highly standardized. Limited equipment and instructional time often lead courses to rely mainly on instructor demonstrations, providing few opportunities for hands-on practice. This "observe more, operate less" pattern creates deficiencies that become apparent in subsequent research, as improper sample preparation can compromise imaging quality and experimental results.

Furthermore, short course durations, high safety risks (e.g., handling liquid nitrogen and toxic reagents), and the high cost and maintenance demands of the instruments further limit independent practice. Key steps are often demonstrated rather than performed, restricting student engagement and motivation [4-5].

2.2 Rigid Teaching System Limiting Tiered Training

Current TEM laboratory courses cover instrument development, electron optics, structural principles, sample preparation and operational demonstrations. Together, these form a comprehensive instructional framework. However, the curriculum structure remains relatively fixed. There is limited clear differentiation between undergraduate and graduate training with respect to learning objectives, content depth and assessment criteria, which makes it difficult to address the distinct competency requirements at different stages of training.

Additionally, some course content does not place sufficient emphasis on recent advances and targeted applications. Emerging research developments and representative case studies are incorporated only limitedly, and instruction continues to rely primarily on lectures and demonstrations. Practical training occupies a relatively small proportion of the course, resulting in a weak link between theoretical instruction and skill development. Consequently, the disconnect between classroom teaching and research practice hinders students' development of applied competencies and innovative capacity.

2.3. Assessment Emphasizes Theory over Practice

Current evaluation methods primarily rely on classroom performance and theoretical examinations, assigning low weight to practical skills and operational competence. Under this assessment orientation, students tend to focus on memorization rather than hands-on practice. Many students demonstrate limited understanding of key technical points during sample preparation and TEM operation and rely heavily on guidance for correct procedures and parameter adjustments. Their ability to independently analyze and solve problems remains underdeveloped.

This assessment approach reduces student engagement in practical learning, impeding comprehensive understanding of TEM workflows and conflicting with the curriculum's goal of integrating theory and practice for talent development.

3. Instructional Reform Strategies

To address fragmented content, limited hands-on participation, and theory-centered assessment in TEM laboratory courses, this study implemented comprehensive instructional reforms, including curriculum optimization, teaching method innovation, integration of research activities, and improvement of evaluation strategies. The course adopted a blended learning approach, combining online and in-person sessions, with process-based assessments that embedded key concepts and technical challenges into daily instruction and evaluation. This structure enabled students to systematically understand TEM principles and gradually master the full workflow of sample preparation, instrument operation, and data analysis, allowing them to select appropriate preparation methods and adjust imaging parameters based on experimental objectives. The approach effectively increased student engagement, enhanced motivation, and supported the development of research skills and scientific thinking.

3.1. Pre-class Preparation

TEM involves a wide range of technical knowledge, specialized terminology, and highly automated, enclosed instrument operation. Achieving learning objectives within limited class time requires effective pre-class preparation. A detailed syllabus outlined learning goals and experimental requirements, emphasizing instrument principles, terminology, operational procedures, and routine maintenance.

A set of online resources—including instructional videos, animations, and lecture slides—was provided through a digital platform. Prior to laboratory sessions, students could organize their study schedule, review materials, and consult literature to prepare systematically. Online discussion forums allowed students to raise questions, while self-assessment and feedback modules enabled instructors to monitor progress and provide targeted guidance. This strategy improved student readiness and laid a solid foundation for efficient hands-on instruction.

3.2. Interactive On-site Teaching

High-quality sample preparation and precise operation are essential for TEM, and lectures alone are insufficient to master key technical skills [6-7]. The course combined theoretical instruction with hands-on practice, using interactive teaching to reinforce understanding of critical procedures.

Small-group instruction (4–6 students per group) ensured that all students participated actively in sample preparation and TEM operation. Students were encouraged to design experiments based on specific objectives, while instructors provided guidance and corrected errors in real time, fostering scientific thinking and problem-solving skills. Each session began with a demonstration of the complete sample preparation workflow, highlighting key steps and precautions. Students then independently prepared samples and conducted imaging. Instructor-student discussions throughout the experiment addressed technical problems and promoted analytical thinking.

At the end of each session, groups presented and discussed their imaging results, focusing on differences in quality and potential improvements. Instructors summarized observations, highlighting common issues and optimization strategies for sample preparation and imaging parameters, further consolidating students' mastery of essential operational techniques.

3.3. Project-Based Learning

Building on basic laboratory training, the course introduced project-based learning to link TEM instruction with research practice. Students participated in university innovation projects and competitions, such as the "Challenge Cup." Under instructor guidance, they completed the full research process, including literature review, experimental design, implementation, and analysis. This approach strengthened experimental design skills, procedural awareness, and data analysis capabilities.

Students worked on topics such as nanomaterials and biological control agents, using TEM to characterize microstructures and interfaces. They optimized sample preparation and imaging parameters to produce reliable experimental results. Project-driven learning enabled students to master standard TEM workflows and select appropriate testing conditions based on research goals, improving data quality and analytical depth. Overall, this approach promoted integration of theory and practice, enhanced understanding and application of advanced characterization techniques, and fostered research skills and innovation.

3.4. Assessment System Improvement

To align with educational goals, the course reformed its evaluation system, shifting from theory-heavy exams to a combination of process-based and outcome-based assessment. A comprehensive framework was implemented, including classroom performance, sample preparation, TEM operation, and theoretical exams, with each component targeting specific skills.

Classroom performance accounted for 20%, evaluating attendance, engagement, and participation in discussions. Sample preparation accounted for 20%, focusing on independent, standardized execution of key TEM techniques, with emphasis on procedural accuracy and attention to detail. TEM operation accounted for 20%, assessing image quality, structural integrity, and parameter adjustment, while considering sample preparation quality to reflect workflow continuity. The theoretical exam accounted for 40%, testing knowledge of TEM principles, technical parameters, and standard procedures.

This combined approach reduced overemphasis on theory, provided a more balanced assessment of practical and conceptual skills, and enhanced the scientific rigor and relevance of course evaluation.

4. Analysis of Teaching Outcomes

The TEM laboratory teaching reform was implemented in the Biology and Biotechnology programs at our university and yielded significant improvements. Adjustments to the curriculum structure, enhancements to teaching methods, closer integration of teaching and research, and the introduction of a diversified assessment system together elevated the overall quality of the course. These changes increased student engagement and motivation, while supporting the coordinated development of theoretical knowledge and practical laboratory skills.

To assess the effectiveness of the reforms objectively, an anonymous survey was conducted at the end of the course. The survey evaluated seven aspects: learning motivation, understanding of theoretical concepts, laboratory skills, research application ability, effectiveness of the reform modules, acceptance of the diversified assessment system, and overall satisfaction. The results are summarized in Table 1.

Table 1: Survey on the Effect of TEM Experimental Teaching Reform (Biology Undergraduates, Grade 2023, n=50)

Survey Item	5	4	3	2	1
Learning Motivation	9%	90%	1%	0	0
Mastery of Theoretical Knowledge (Principles/Terminology)	12%	86%	2%	0	0
Experimental Proficiency (Sample Preparation + Instrument Operation)	13%	85%	2%	0	0
Reform Module Effectiveness (Pre-class + Interactive Sessions)	20%	75%	5%	0	0
Research Application Capability	13%	85%	2%	0	0
Recognition of Diversified Assessment	55%	45%	0	0	0
Overall Teaching Satisfaction	57%	43%	0	0	0

Scoring Definition: 5 = Excellent; 4 = Good; 3 = Fair; 2 = Poor; 1 = Ineffective

Survey Notes: The survey was conducted anonymously, with a 100% valid response rate.

The survey results show that students were highly satisfied across all measured aspects. Ninety-nine percent reported that the teaching reform notably increased their learning motivation, and more than 95% rated their mastery of theoretical knowledge and experimental skills as "good" or above, confirming the overall effectiveness of the reforms. The survey also identified areas for improvement, including a deeper understanding of vacuum system principles, additional training for techniques such as ultra-thin sectioning, and wider incorporation of interdisciplinary research applications. Students responded positively to the "preparation plus interaction" teaching approach and the diversified assessment system, suggesting more support for pre-class questions and slightly longer interactive sessions. Overall, the reforms successfully met students' learning needs and course objectives, providing a solid basis for continued refinement and optimization.

5. Conclusion

Integrating large-scale precision instruments into laboratory teaching is an effective way for universities to cultivate high-quality, innovative talent. This study examined the TEM laboratory course to address the limitations of traditional experimental courses in content design and instructional methods. Targeted reforms were implemented in curriculum structure, teaching strategies, research-oriented practice, and assessment practices. The result was a well-rounded experimental teaching framework.

The findings suggest that this framework, which is oriented towards students' research learning needs, encourages active participation and enhances their learning engagement. It strengthens their understanding of TEM-related theories and technical principles, and improves their practical laboratory skills and research competence. This provides them with a solid foundation for future scientific work. These results provide valuable insights into the effective integration of large-scale instruments into biology laboratory education.

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7.References

1. Lu Y, Chen YF, Liu QQ, *et al*. Current status and preliminary reform of postgraduate teaching for transmission electron microscopy technology. Shandong Chem Ind. 2021;50(22):211-3.
2. Zhao WE, Wang ZB, Xia ZR, *et al*. Teaching arrangement and experience of transmission electron microscopy for undergraduate students in basic medicine. Basic Med Educ. 2017;19(6):431-3.
3. Kong L. Teaching practice of high-resolution transmission electron microscopy training: Observation of lattice fringes of gold nanoparticles as an example. China Mod Educ Equip. 2025;(1):45-7.
4. Su HB, Huang WY, Li H, *et al*. Application of a student-centered diversified teaching model in biochemistry education. Univ Educ. 2019;(8):98-100.
5. Qin QQ, Sun FZ, Ning YK. Application of transmission electron microscopy in experimental teaching research. Shandong Chem Ind. 2020;49(15):219-20.
6. Zhang L. Practice and exploration of operation and management of transmission electron microscopy. Exp Technol Manag. 2020;(2):168-70. doi:10.16791/j.cnki.sjg.2020.02.063
7. Ma XM. Practical course of TEM sample preparation in electron microscopy specialized teaching. Lab Res Explor. 2021;40(11):215-7. doi:10.19927/j.cnki.syyt.2021.11.047

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