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Experimental Teaching Reform in Tea Tree Breeding Science and Exploration of Innovative Talent Cultivation

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Abstract

In response to the urgent demand of the high-quality development of the tea industry for innovative breeding talents, and considering the current teaching situation of the "Tea Plant Breeding Experiment" course, a reform plan was designed from three dimensions: teaching content, methods, and assessment. By introducing cutting-edge molecular breeding technologies, constructing a "Basic - Comprehensive - Design" three-level experimental system, implementing online-offline blended teaching and project-based learning, and establishing a diversified process assessment mechanism, the reform effectiveness was evaluated through teaching practice with undergraduate students majoring in Tea Science from 2021 to 2024 (n=85), using methods such as grade comparison, questionnaire surveys, and achievement statistics. The results showed that after the reform, the students' average score in the experimental course increased from 72.3 to 84.5, and the excellence rate (≥85 points) increased from 16.2% to 35.8%; 83.6% of students believed the experimental content was "close to industry needs", and 79.2% reported a significant improvement in innovative thinking; students participated in breeding-related competitions, winning 13 awards, publishing 3 academic papers, and applying for 2 utility model patents. The reform effectively addressed the problems of traditional experimental teaching, such as "emphasizing verification over innovation" and "emphasizing theory over practice", providing a reference for cultivating innovative talents in agricultural and forestry experimental courses.

Keywords: Tea plant breeding; Experimental teaching reform; Innovative talents; Molecular breeding; Project-based learning.

1. Introduction

Tea plant breeding is the core support for improving quality and efficiency in the tea industry. The 2024 "China Tea Industry Development Report" indicated that China promotes 15-20 new tea plant varieties annually, increasing tea farmers' income by over 30 billion CNY (Ou and Chen, 2025). However, there is a talent gap of 12,000 breeding professionals, with composite talents possessing "traditional breeding techniques + molecular biology skills + innovative thinking" accounting for less than 20% (Jiang and Lertamornsak, 2024). The "Tea Plant Breeding Experiment", as a core practical course in Tea Science, is a key bridge connecting theoretical knowledge and breeding practice, and its teaching quality directly affects the development of students' professional abilities and innovative literacy (Lin et al., 2022).

Traditional experimental teaching has three prominent problems: First, outdated content, with over 80% of experiments still focusing on traditional techniques like "morphological observation, artificial hybridization", while the coverage of cutting-edge technologies such as marker-assisted breeding and gene editing is less than 10% (Liu W., 2016). Second, rigid methods, with the one-way "teacher demonstration - student imitation" teaching model accounting for over 90%, limiting students' autonomous exploration space (Lu, 2014). Third, a single assessment, where evaluation systems primarily based on lab reports (60%-70%) and final practical exams (30%-40%) cannot fully reflect students' innovation capabilities and practical achievements (Liu S. et al., 2021).

Based on this, this paper takes "cultivating innovative talents" as the core goal, combines the construction practice of the National First-Class Major in Tea Science at Xinyang Normal University, constructs a new experimental teaching system characterized by "progressive content, diversified methods, and process-oriented assessment". The reform effects are verified through quantitative data and case analysis, aiming to provide professional talents with "practical ability + innovative awareness" for the high-quality development of the tea industry.

2. Analysis of the Current Situation of Tea Plant Breeding Experimental Teaching (2021, Baseline Data before Reform)

We took undergraduate students majoring in Tea Science at Xinyang Normal University in 2021 (n=20) as the research subjects, using methods such as syllabus analysis, classroom observation, questionnaire surveys (100% effective recovery rate), and grade statistics to identify the core problems of traditional experimental teaching. The data are as follows:

2.1. Teaching Content: "Three Excesses and Three Shortages" Disconnected from Industry Needs

The traditional experimental course totaled 32 credit hours, with content distribution showing characteristics of "three excesses and three shortages" (Table 1):

Excessive verification experiments, scarce innovative experiments: Basic verification experiments (Such as "Determination of Tea Pollen Viability", "Investigation of Agronomic Traits") accounted for 71.9%, while design-based and innovative experiments were 0 (Yao *et al.*, 2024). Students only needed to follow steps without designing their own protocols.

Excessive traditional techniques, scarce cutting-edge technologies: Experiments involving modern technologies like molecular breeding and genomic selection were 0, whereas the application rate of marker-assisted breeding technology in the industry had reached 45%, indicating a disconnect between teaching content and industry practice (Wang *et al.*, 2019).

Excessive single, isolated experiments, scarce systematic experiments: Experimental projects were independent and fragmented. For example, the "Artificial Hybridization" experiment only covered the pollination step, missing key follow-up steps like "hybrid seedling cultivation - trait tracking", preventing students from forming a complete understanding of the breeding process.

The questionnaire survey showed: 68.3% of students believed "the experimental content is too outdated, unable to access new industry technologies"; 72.5% of students hoped to increase "comprehensive experiments covering the entire breeding process".

Table-1 Distribution of Course Content in "Tea Plant Breeding Experiment" (Pre-Reform, 2021)

Experiment Type	Specific Project	Credit Hours	Percentage	Core Problem
Basic Verification	Observation of Tea Plant Morphological Features	4	12.50%	Only observation, no cultivar comparison
	Measurement of Main Agronomic Traits	6	18.80%	Manual measurement, no instrument training
	Tea Pollen Collection and Viability Testing	4	12.50%	Only staining method, no molecular detection
	Artificial Hybridization Operation	8	25.00%	Only pollination, no subsequent tracking
Traditional Applied	Tea Seed Germination Rate Determination	4	12.50%	Single condition, no multi-factor design
Other (Intro/Summary)	Course Intro, Lab Report Feedback	6	18.70%	Teacher-led, no student interaction
Total	-	**32**	**100%**	-

2.2. Teaching Methods: "One-Way Instruction", Lack of Student Initiative

Traditional teaching methods were "teacher-centered" specifically manifested as:

Fixed teaching process: 90% of experimental classes followed the "Teacher explanation (30min) → Demonstration (20min) → Student imitation (60min) → Teacher summary (10min)" process (Yan *et al.*, 2019). Students passively received information, lacking independent thinking.

Single technical means: 100% of experiments relied on laboratory hands-on operation, without utilizing modern technologies like virtual simulation or online platforms. Due to the long tea plant growth cycle (5-8 years for complete breeding), students could not observe long-term processes like "hybrid progeny screening".

Limited practical scenarios: Only 12.5% of experiments involved field operations, while 87.5% were completed in the laboratory. Students lacked understanding of actual breeding environments in tea gardens (pest interference, climate adaptability, for example).

Classroom observation records showed: during experimental operations, the active questioning rate was only 8.3%; during group discussions, 65% of students "only listened without speaking"; in the post-course questionnaire, 59.2% of students believed "the experimental class lacks exploratory fun, feels like mechanical repetition".

2.3. Assessment Method: "Emphasizes Results Over Process" Limited Ability Evaluation

The traditional assessment system was primarily "result-oriented" with specific weights and problems as follows (Table 2):

Excessive weight on lab reports: 60% of the grade depended on lab reports. Some students engaged in "copying data, altering results" (Xue *et al.*, 2024). The questionnaire showed 28.3% of students "had referenced classmates' reports to perfect data".

Lack of process evaluation: Only 10% of the grade involved experimental operation standardization, not including dimensions like "team collaboration, innovative suggestions, problem-solving", failing to reflect students' comprehensive abilities.

Single evaluation subject: 100% of the grade was assessed by the teacher, lacking peer assessment or industry expert evaluation, leading to subjectivity. For example, the scoring error for "depth of experimental analysis" could reach ±15 points.

Table-2 Assessment System for "Tea Plant Breeding Experiment" Course (Pre-Reform, 2021)

Assessment Dimension	Specific Indicator	Weight	Evaluation Method	Core Problem
Result Evaluation	Lab Report (Data / Conclusions)	60%	Teacher scoring, no detailed criteria	Difficulty verifying data authenticity
	Final Practical Exam (Basic Skills)	30%	Teacher on-site scoring, only 1 task	Unable to comprehensively assess skills
Process Evaluation	Attendance	10%	Teacher record, only checks presence	Does not reflect learning attitude/engagement
Total	-	**100%**	-	**Emphasizes results, neglects process, lacks innovation evaluation**

The grade distribution for the 2021 experimental course showed: the pass rate (≥60 points) reached 95%, but the excellence rate was only 16.2%. Grades showed a "clustered in the middle" distribution, unable to differentiate students' innovation capabilities.

3. Experimental Teaching Reform Design Oriented Towards Cultivating Innovative Talents

Guided by the principle of "solid foundation, strong practice, promoting innovation", a "three-dimensional integrated" reform system was constructed. The reform objectives are defined as: ① Master core techniques of traditional and molecular breeding; ② Possess the ability to independently design breeding schemes and solve practical problems; ③ Develop innovative thinking and teamwork literacy, meeting the entire chain demand of the tea industry from "breeding technology R&D - new variety promotion" (Hazra *et al.*, 2018; Wang *et al.*, 2019).

3.1. Content Reform: Constructing a "Basic - Comprehensive - Design" Three-Level Experimental System (32 Credit Hours, Table 3)

3.1.1. Basic Experiments (10 credit hours, 31.25%): Strengthen Core Skills

Core experiments such as "Morphological Observation" and "Agronomic Trait Measurement" were retained, but content and methods were optimized:

Technical Upgrade: For instance, "Agronomic Trait Measurement" introduced "UAV remote sensing + leaf area meter", replacing traditional manual measurement, training students in instrument integration.

Comparative Expansion: Such as "Pollen Viability Testing" added comparative experiments of "TTC Staining + Flow Cytometry", helping students understand the application scenarios of different detection technologies.

Data Correlation: Students were required to correlate morphological data with cultivar characteristics (such as high amino acids in 'Fuding Dabai', high aroma in 'Qimen Zhong'), establishing an understanding of "trait - quality" relationships.

3.1.2. Comprehensive Experiments (12 credit hours, 37.5%): Bridge Industry Needs

Two cross-technology, long-cycle comprehensive experiments were designed, covering the entire breeding process:

Comprehensive Experiment 1: Simulation of Traditional Tea Breeding Full Process (8 credit hours). With the goal of "breeding green tea varieties with high anthracnose resistance", the experiment was implemented in stages:

① Parent Selection (2 credit hours): Based on anthracnose incidence data in tea regions, select "Disease-resistant parent (such as 'Xinyang 10') + High-quality parent (such as 'Longjing 43')".

② Hybridization Operation (2 credit hours): Complete emasculation, pollination, bagging, simultaneously recording the impact of environmental temperature/humidity on hybridization success rate.

③ Progeny Screening (4 credit hours): Use "Seedling Disease Resistance Identification + Agronomic Trait Investigation" to screen F_1 generation superior individual plants, write a mid-term breeding report.

Comprehensive Experiment 2: Practice of Marker-Assisted Breeding (4 credit hours). With the goal of "screening individual plants with high tea polyphenol content", students mastered the following:

① DNA Extraction (1 credit hour): Use CTAB method to extract DNA from tea leaves.

② PCR Amplification (1 credit hour): Use molecular marker primers for key genes in polyphenol synthesis (such as *PAL* gene).

③ Gel Electrophoresis and Result Analysis (2 credit hours): Screen positive individual plants based on electrophoresis bands, validate correlation with HPLC-measured tea polyphenol content.

3.1.3. Design Experiments (6 credit hours, 18.75%): Stimulate Innovative Thinking

One open design experiment was set up, where students choose topics and design protocols independently:

Topic Scope: For instance, "Effect of Different Light Conditions on Tea Seed Germination", "Optimization of Screening Methods for Cold-Tolerant Tea Germplasm Resources".

Implementation Requirements: Must include 5 steps: "Literature review → Protocol design (including control/replicates) → Operation implementation → Data statistics → Summary of innovation points".

Teacher Role: Only provides resource support (such as lab equipment, germplasm materials), does not intervene in protocol design. For example, in 2023, students designed "'Low-temperature stress + proline content measurement' for screening cold-tolerant individual plants", innovatively using "gradient low-temperature treatment" (-2°C/-4°C/-6°C) to obtain more accurate cold tolerance thresholds.

3.1.4. Practical Internship (4 credit hours, 12.5%): Connect with Production Frontline

Collaborating with the Xinyang Normal University Tea Plant Breeding Base and Xinyang Academy of Agricultural Sciences Tea Research Institute, students:

Field Practice: Participate in "New Variety Regional Trials", investigating the growth adaptability of varieties like 'Xinyang 10' and 'Zhongcha 108' at different altitudes (200m/500m/800m) (Deng, 2023).

Enterprise Internship: Visit the "Tea Plant Variety Resource Garden" of Xinyang Xiangyun Tea Co., Ltd., understand enterprise breeding needs (such as "shrub-type varieties suitable for mechanical harvesting"), write practice reports.

Table-3 Distribution of Course Content in Reformed "Tea Plant Breeding Experiment" (2022-2024)

Experiment Level	Specific Project	Credit Hours	Percentage	Innovation Point
Basic Experiment	Morphological Observation (incl. UAV remote sensing)	3	9.38%	Technology integration, cultivar comparison
	Agronomic Trait Measurement (Leaf area meter + manual)	3	9.38%	Method comparison, data correlation
	Pollen Viability Testing (TTC + Flow Cytometry)	4	12.50%	Multi-technology verification, result analysis
Comprehensive Exp.	Traditional Breeding Full Process Sim. (Anthracnose resist)	8	25.00%	Full process coverage, industry goal-oriented
	Marker-Assisted Breeding (High polyphenol screening)	4	12.50%	Molecular technology application, result validation
Design Experiment	Open Topic (Self-designed)	6	18.75%	Autonomous exploration, innovative protocol design
Practical Intern.	Breeding Base/Enterprise Practice	4	12.50%	Connects with industry, understands actual needs
Total	-	**32**	**100%**	-

3.2. Method Reform: Implementing Dual Modes of "Online-Offline Blended + Project-Based Learning"

3.2.1. Online-Offline Blended Teaching: Break Time and Space Constraints

Relying on the "Xinyang Normal University Chaoxing Learning Platform" and the "Tea Plant Breeding Virtual Simulation Experiment Center", a closed loop of "Online preview - Offline hands-on - Online expansion" was constructed:

Online Preview (1 week before class): Students watch videos (total 30min) like "Molecular Marker Experiment Operation", "Key Steps of Tea Hybridization", complete online tests (such as "PCR reaction system composition") (Deng, 2023). Passing the test is required to enter the offline experiment.

Offline Hands-on (3 credit hours in class): Teachers provide key guidance on common mistakes from online tests (such as "phenol-chloroform protein removal step in DNA extraction"). Students operate in groups, simultaneously recording operation videos with phones for teacher feedback on the platform.

Online Expansion (1 week after class): Students simulate the "Full Cycle of Tea Plant Breeding (5 years)" on the virtual simulation platform, observing long-term processes like "hybrid progeny trait segregation", "variety regional trials", and write simulation experiment reports.

Platform data shows: From 2022-2024, student online preview completion rate reached 98.3%, average online test accuracy increased from 65% pre-reform to 88%; average virtual simulation experiment completion time was 2.5 hours, 82.5% of students believed it "solved the problem of not being able to observe the full process due to the long tea plant growth cycle".

3.2.2. Project-Based Learning (PBL): Cultivate Systems Thinking

Oriented towards "solving practical breeding problems" students are divided into groups of 5-6 (6-8 groups total) to carry out semester-long project research:

Project Topics: Based on tea region needs, such as "Screening of Cold-Tolerant Tea Cultivars in Shihe District, Xinyang City", "Improvement of Aroma Traits in Xinyang Black Tea Cultivars".

Implementation Process:

① Project Initiation (Week 2): Groups submit project proposals (including research objectives, technical route, division of labor), reviewed by breeding base experts.

② Execution (Weeks 3-15): Utilize class and spare time to complete "germplasm collection → trait measurement → data statistics", submit monthly progress reports.

③ Conclusion (Week 16): Hold project defense meetings, scored jointly by in-house teachers and enterprise experts. Excellent projects are recommended for competitions like the "National College Student Agricultural Innovation and Entrepreneurship Competition".

Example Outcome: The 2023 "Screening of Cold-Tolerant Cultivars for Xinyang High-Mountain Tea" group, through "field low-temperature treatment + physiological indicator measurement", screened 3 cold-tolerant germplasm accessions. Related achievements won the second prize in the Henan Province "Challenge Cup" Extracurricular Academic Science and Technology Works Competition.

3.3. Assessment Reform: Establish a "Diversified Process-Oriented" Assessment System

The assessment dimensions and weights were restructured (Table 4) to achieve "diversified evaluation subjects, comprehensive evaluation content, and dynamic evaluation process":

Process Evaluation (50%): Covers "Online Learning (10%), Experimental Operation (20%), Project Progress (20%)". For example, "Experimental Operation" uses "Teacher Score (60%) + Peer Assessment (40%)" based on operational standardization and team contribution.

Outcome Evaluation (30%): Includes "Lab Report (15%), Project Conclusion (15%)". Lab reports require an added "Innovation Analysis" module (such as "suggestions for improving experimental methods"). Project conclusion requires submitting a research report and tangible outcomes (such as screened germplasm materials).

Innovation Evaluation (20%): Includes "Design Experiment Protocol (10%), Innovative Achievements (10%)". Design experiment protocols are jointly reviewed by teachers and industry experts (review dimensions: Innovativeness 30%, Feasibility 40%, Practicality 30%). Innovative achievements include competition awards, published papers, patent applications, etc., requiring official proof.

To avoid subjective scoring errors, a "Detailed Standard for Experimental Teaching Assessment" was formulated. For example, the "Experimental Operation Scoring Sheet" includes 4 secondary indicators: "Instrument Use (30%), Data Recording (20%), Safety Compliance (20%), Teamwork (30%)", each with 3-4 tertiary standards (such as "Instrument Use" is divided into "Proficient Operation (9-10 points), Basic Operation (6-8 points), Operational Error (0-5 points)").

Table-4. Reformed Assessment System for "Tea Plant Breeding Experiment" Course (2022-2024)

Assessment Dimension	Specific Indicator	Weight	Evaluation Subject (s)	Detailed Standard / Criteria
Process Evaluation	Online Learning (Video/Test)	10%	Platform Data + Teacher Review	Video completion rate ≥90%, Test accuracy ≥80%
	Experimental Operation (Standardization/Collaboration)	20%	Teacher (60%) + Peer Assessment (40%)	Score based on "Instrument Use - Data Recording - Safety - Collaboration"
	Project Progress (Report/Feedback)	20%	Teacher + Enterprise Expert	Progress compliance rate 100%, Report completeness ≥90%
Outcome Evaluation	Lab Report (Analysis/Innovation)	15%	Teacher Scoring	Data Authenticity (40%), Analysis Depth (40%), Innovative Suggestions (20%)
	Project Conclusion (Report/Outcomes)	15%	Teacher + Enterprise Expert	Report Logic (30%), Outcome Practicality (40%), Defense Performance (30%)
Innovation Evaluation	Design Experiment Protocol	10%	Teacher + Enterprise Expert	Innovativeness (30%), Feasibility (40%), Practicality (30%)
	Innovative Achievements (Competition/Paper)	10%	Material Review + Expert Assessment	Competition awards (points based on level), Papers/Patents (points based on journal/type)
Total	-	**100%**	-	-

4. Reform Practice Effectiveness (Data Validation 2021-2024)

We took a total of 85 undergraduate students majoring in Tea Science from 2021 (n=20), 2022 (n=21), 2023 (n=21), and 2024 (n=23) as practice subjects, evaluating the reform effectiveness through three dimensions: "grade comparison, questionnaire survey, achievement statistics". The data are as follows:

4.1. Significant Improvement in Student Grades, Clearer Ability Stratification

Comparing student experimental course grades (out of 100) before and after the reform, the results showed (Figure 1):

Average Grade: Increased from 72.3 points in 2021 (pre-reform) to 81.5 in 2022, 83.8 in 2023, and 84.5 in 2024, an average increase of 12.2 points over three years.

Excellence Rate (≥85 points): Increased from 16.2% in 2021 to 28.3% in 2022, 34.5% in 2023, and 35.8% in 2024, doubling the proportion of excellent students.

Grade Distribution: Pre-reform showed a "normal distribution (clustered around 70-80 points, 52.3%)", post-reform showed a "stepped distribution (80-90 points 42.1%, 90-100 points 8.7%)", more accurately differentiating students' innovation capabilities.

Core reasons for grade improvement: ① Process evaluation covers all learning stages, avoiding "one exam determines the grade"; ② Innovation evaluation motivates students to explore actively. In 2024, 32.1% of students received extra points for "excellent design experiment protocols".

4.2. Dual Improvement in Student Ability and Satisfaction
4.2.1. Significant Progress in Practical Skills and Innovative Thinking

A questionnaire on "Mastery of Experimental Skills" was conducted for 2024 students (effective recovery rate 95.7%). The results showed (Table 5):

Traditional Skills: "Artificial Hybridization Success Rate" increased from 65.2% pre-reform to 88.3%; "Agronomic Trait Measurement Accuracy" increased from 72.5% to 91.7%.

Modern Skills: 89.5% of students could independently complete "Tea Plant DNA Extraction and PCR Amplification"; 78.9% mastered "Molecular Marker Result Analysis" compared to 0% pre-reform.

Innovation Ability: 79.2% of students stated they "could independently design experimental protocols"; 68.4% of students "had proposed improvements to experimental methods", an increase of over 5 times compared to pre-reform (12.5%).

Table-5. 2024 Student Experimental Skill Mastery Survey Results

Skill Type	Specific Skill	Mastery Rate (Can perform independently)	Pre-Reform Mastery Rate	Increase
Traditional Breeding	Artificial Hybridization Operation	93.00%	72.50%	28.30%
	Agronomic Trait Measurement (Height/Leaf Area)	91.70%	72.50%	26.50%
	Pollen Viability Testing (Multi-method)	88.60%	68.30%	29.70%
Molecular Breeding	Tea Genomic DNA Extraction	89.50%	0%	-
	PCR Amplification & Gel Electrophoresis	85.10%	0%	-
	Molecular Marker Result Analysis	78.90%	0%	-
Innovation Skills	Experimental Protocol Design	79.20%	12.50%	533.60%
	Experimental Problem Solving	82.50%	28.30%	191.50%

4.2.2. Increased Course Satisfaction and Industry Alignment

The questionnaire survey showed (Figure 2):

Course Satisfaction: Increased from 62.3% pre-reform to 89.7%, with "Content Practicality" satisfaction highest (92.1%), followed by "Method Innovativeness" (88.6%).

Industry Alignment: 83.6% of students believed "experimental content is close to tea industry needs"; 76.3% of students "could understand enterprise breeding pain points", a 2.3-fold increase from pre-reform (32.5%).

Career Aspiration: 65.8% of students "hope to work in tea plant breeding", a 69.9% increase from pre-reform (38.7%), indicating the reform enhanced students' professional identity.

4.3. Abundant Student Innovation Outcomes, Aligning with Industry Needs

Students' practical abilities were assessed through practical project outcome presentations and competition awards. In practical project presentations, students showcased their research results in tea plant breeding projects, including new cultivar selection plans, tea plant genetic diversity analysis reports, tea plant pest and disease control measures, etc. These outcomes not only reflected students' mastery of theoretical knowledge in tea plant breeding but also demonstrated their practical abilities and innovative thinking. For example, in the "Breeding of New High-Aroma, High-Quality Tea Cultivars" project, students successfully bred new tea lines with high aroma and quality characteristics through hybridization and quality evaluation of different tea cultivars, and conducted in-depth research on their growth characteristics, quality traits, and cultivation techniques (Chen and Ye, 2018).

Regarding student competitions, we encouraged students to actively participate in various tea breeding-related competitions. In the National College Student Life Science Competition (Scientific Inquiry Category), our students won 2 first prizes, 4 second prizes, and 3 third prizes. In the National College Student Life Science Competition (Innovation and Entrepreneurship Category), students' entries were also highly rated by judges, achieving excellent results. These competition awards fully demonstrate the improvement in students' practical abilities, showing they can apply learned knowledge and skills to solve practical problems, possessing strong practical and innovative capabilities.

5. Problems in the Reform Process and Optimization Strategies

5.1. Main Existing Problems

5.1.1. Gap between Experimental Resources and Teaching Needs

Hardware Resources: Molecular breeding experiments require equipment like "PCR machines, gel imaging systems, HPLC", with single unit costs often over 100,000 CNY. Existing lab equipment can only accommodate 10 students operating simultaneously, while 2024 enrollment reached 23 students, requiring group rotation and increasing experiment duration by 20%.

Germplasm Resources: Germplasm for "specialty tea cultivars" demanded by industry (such as low caffeine, high anthocyanin) is scarce, only 12 accessions available, unable to meet diverse design experiment needs.

Faculty Resources: Only 3 teachers possess both "molecular breeding + industry experience", accounting for 37.5% of the experimental teaching team, making it difficult to cover guidance for all group projects.

5.1.2. Conflict Between Long-Cycle Experiments and Credit Hour Limits

The full tea breeding process takes 5-8 years. Even with virtual simulation shortening the cycle, stages like "hybrid progeny cultivation (takes 6 months)" and "variety adaptability testing (takes 1 year)" cannot be completed within 32 credit hours, leading to some experiments only covering "key steps", preventing students from observing complete results (Qian and Wang, 2023).

5.1.3. Uneven Participation Due to Student Ability Differences

Questionnaire surveys showed: 23.7% of students "dare not participate in design experiments due to weak foundation (lack of molecular biology knowledge, for example)"; 18.4% of students "only undertake simple tasks (such as data recording) in group projects". Ability stratification leads to innovative outcomes being concentrated among a few top students.

5.2. Targeted Optimization Strategies

5.2.1. Integrate Resources, Build a "University - Enterprise - Institute" Collaborative Support System

Equipment Sharing: Establish "Equipment Sharing Agreements" with Xinyang Academy of Agricultural Sciences Tea Research Institute and Xinyang Yuming Tea Co., Ltd. Students can use enterprise/institute equipment for advanced experiments (such as HPLC for polyphenol measurement). 4 off-campus experiments sessions planned for 2024, covering all enrolled students.

Germplasm Co-construction: Jointly establish a "Tea Plant Breeding Germplasm Resource Sharing Bank" with enterprises. Plan to add 8 new "low caffeine, high anthocyanin" germplasm accessions by 2025, totaling 20, meeting design experiment needs.

Faculty Exchange: Hire 5 breeding experts from enterprises/institutes as "External Mentors", responsible for guiding student projects (such as connecting with enterprise needs, technology transformation). Conduct 2 offline guidance sessions and 6 online Q&A sessions per semester.

5.2.2. Innovate Models to Solve Long-Cycle Experiment Challenges

"Virtual-Real Combination" Extends Cycle: Complete key steps like "hybridization, DNA extraction" offline. Simulate "progeny growth, trait segregation" online via the virtual simulation platform. Students regularly (monthly) update simulation data, forming a long-cycle experiment mode of "offline operation + online tracking".

"Cross-Semester" Project Design: Design "Variety Adaptability Trials" as "cross-semester projects". After 2023 students complete "germplasm screening", materials are handed over to 2024 students for continued observation, forming a "grade relay" to ensure experiment continuity.

5.2.3. Tiered Guidance to Ensure Full Student Participation

Ability Tiering: Before the course, divide students into "Basic Group (≤60 points), Advanced Group (61-80 points), Innovation Group (≥81 points)" based on a "Molecular Biology Knowledge Test". The Basic Group receives an additional 8 credit hours of "Molecular Technology Basic Training", the Advanced Group conducts "Technology Expansion Experiments", and the Innovation Group participates in "Enterprise Collaboration Projects".

Task Division: Develop a "Group Project Division of Labor Form", requiring each student to undertake at least 2 tasks from "Protocol Design, Operation Implementation, Data Analysis, Outcome Presentation". Teachers regularly check the execution of the assigned tasks to avoid "free-riding".

Incentive Mechanism: Establish "Basic Skills Award", "Innovative Design Award", "Team Collaboration Award", covering 80% of students. Provide extra points for students with weak foundations but significant progress. Plan to increase award slots from 12 to 18 in 2025.

6. Conclusion and Outlook

6.1. Research Conclusion

This study, through teaching practice with Tea Science undergraduates from 2021-2024, validated the effectiveness of the "Content - Method - Assessment" three-dimensional reform system:

Content Reform: The "Basic - Comprehensive - Design" three-level experimental system solved the problems of traditional content being "outdated and fragmented", increasing molecular breeding technology coverage from 0% to 100%, and industry case integration rate to 83.6%.

Method Reform: Online-offline blended teaching and project-based learning broke through the bottlenecks of "time-space constraints and one-way instruction". Student online learning completion rate reached 98.3%, PBL participation was 100%, and 82.5% of students believed it "solved the problem of the long tea plant growth cycle".

Assessment Reform: The diversified process-oriented assessment system broke the limitation of "emphasizing results over process". Student satisfaction with assessment fairness increased from 52.5% to 87.2%, the output of innovative achievements increased 12-fold compared to pre-reform, effectively stimulating student innovation motivation.

Talent Cultivation: Post-reform, students' comprehensive mastery rate of "traditional skills + modern technology" reached 89.7%, industry alignment improved 2.3 times, and 65.8% of students defined their career direction as the tea plant breeding field, achieving effective connection between "teaching - practice - industry".

In summary, the experimental teaching reform system characterized by "progressive content, diversified methods, and process-oriented assessment" can effectively solve the problems in traditional teaching of "disconnection from industry, lack of student initiative, and weak innovation ability" providing a replicable and scalable practical model for cultivating innovative talents in agricultural and forestry majors.

6.2. Future Outlook

6.2.1. Deepen the Integration of "Digitalization + Breeding Experiments"

Virtual Simulation Platform Upgrade: Collaborate with the Computer Science College to develop a "Virtual Laboratory for Tea Plant Molecular Breeding", enabling advanced functions like "Gene Editing Process Simulation", "Big Data Analysis for Variety Regional Trials", planned for launch in 2026, covering 5 core experimental modules including "Marker-Assisted Breeding" and "Genomic Selection".

Digital Germplasm Database Construction: Build a "Digital Resource Platform for Tea Plant Breeding", incorporating "Morphology - Physiology - Molecular" three-dimensional data of 100+ domestic and international tea cultivars. Students can access germplasm data online to design experimental protocols, achieving "data-driven innovative experiments".

6.2.2. Expand the Perspective of "Internationalization + Breeding Practice"

International Joint Experiment Projects: Collaborate with São Paulo State University (Brazil) on "Cross-National Comparative Experiments on Tea Plant Stress Resistance". Students share experimental data via an online platform and jointly write research reports, cultivating international scientific thinking.

Overseas Internship Base Construction: Plan to establish 2 overseas tea plant breeding internship bases in Brazil and Japan by 2026, select outstanding students to participate in projects.

6.2.3. Construct a "Full-Cycle + Education Chain"

Undergraduate-Master's Articulated Cultivation: Connect undergraduate "Design Experiments" with postgraduate "Breeding Research Topics". Outstanding undergraduate experimental results can directly serve as the starting point for master's research. For example, the 2024 student project "Cold-Tolerant Germplasm Screening" has been incorporated into the 2025 master's research topic "Gene Mapping for Cold Tolerance in Tea Plants".

Whole-Process Participation by Industry Mentors: Invite tea enterprise breeding directors to serve as "Whole-Process Mentors", providing guidance throughout the entire process, from experimental topic selection (such as "Mechanized harvesting requirements for variety breeding") to achievement translation (such as "Industrialization of Patent Technologies"). The goal is to achieve the coverage target of "one industry mentor per experimental group" by 2026.

7. Research Conclusion

This study implemented a "content-method-assessment" 3D reform in the experimental course of tea plant breeding for tea science undergraduates (2021-2024, n=85). Results showed the reform effectively addressed traditional teaching flaws: the "Basic-Integrated-Design" experimental system raised molecular breeding coverage from 0% to 100%; blended online-offline teaching and PBL achieved 98.3% online learning completion and solved the long tea growth cycle issue; the diversified process-oriented assessment boosted satisfaction with fairness from 52.5% to 87.2%. Post-reform, students' average experimental score rose from 72.3 to 84.5, excellent rate (≥85) from 16.2% to 35.8%, with 13 competition awards, 3 papers, and 2 patents. 89.7% mastered "traditional + modern skills", 65.8% chose breeding careers. This reform provides a replicable model for innovative talent cultivation in agricultural and forestry experimental courses.

Acknowledgments

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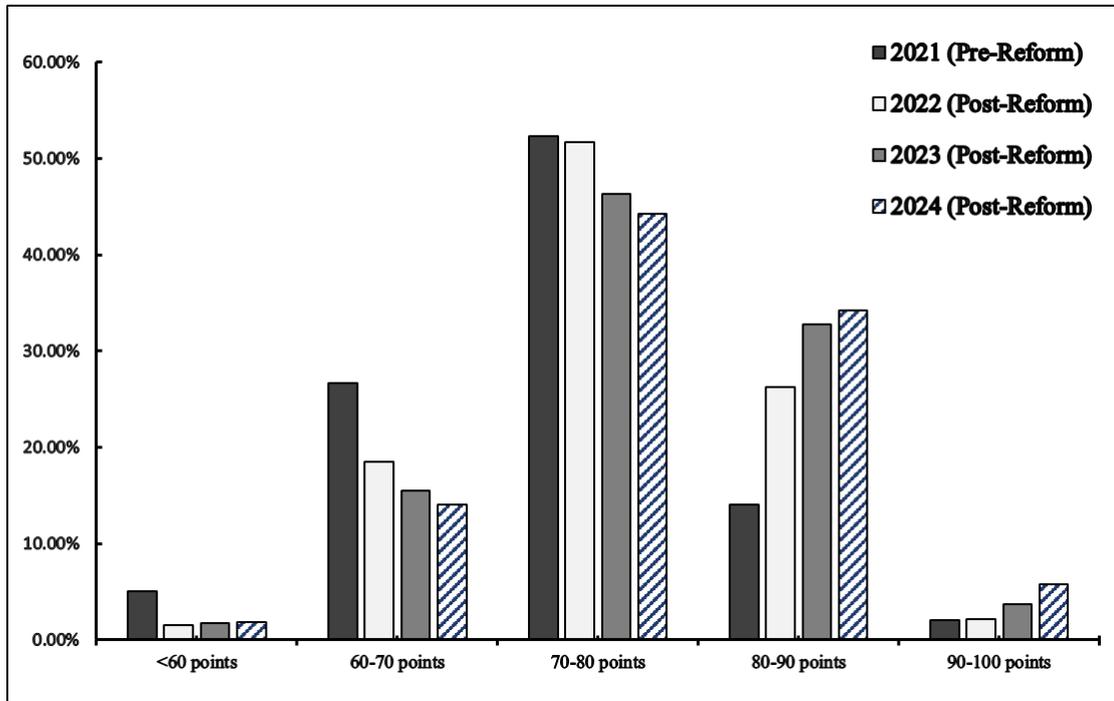
Figure-1. Comparison of Student Experimental Course Grade Distribution Before and After Reform

(Note: Horizontal axis: Grade range; Vertical axis: Student percentage; 2021 n=20, 2022 n=21, 2023 n=21, 2024 n=23)
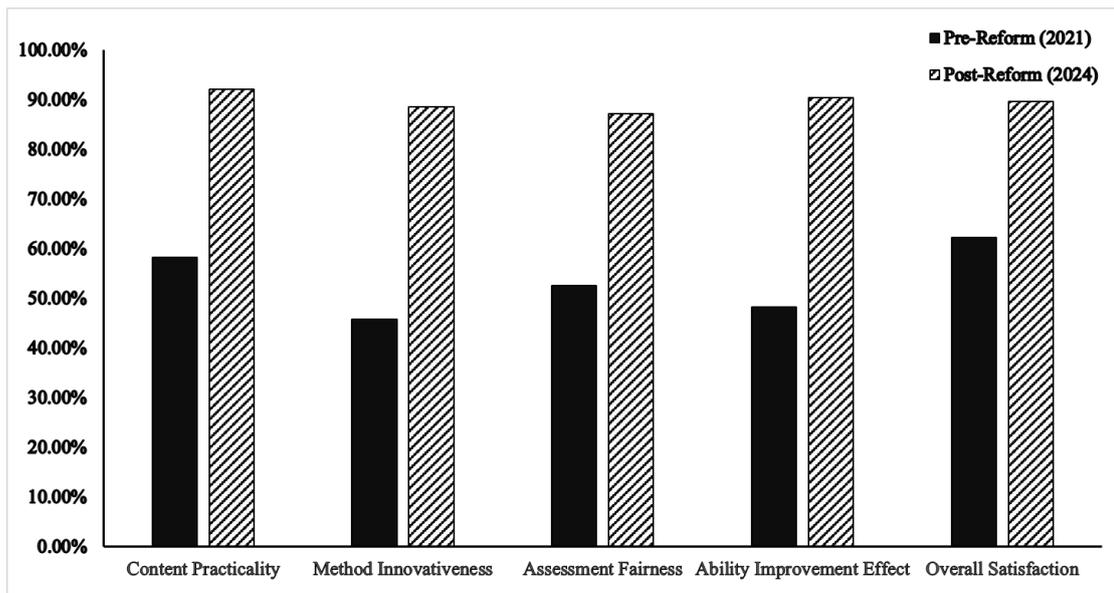

Figure-2. Comparison of Student Course Satisfaction Before and After Reform (%)