Future Technology
Open Access Journal
ISSN 2832-0379

August 2025| Volume 04 | Issue 03 | Pages 182-192

Journal homepage: https://fupubco.com/futech

https://doi.org/10.55670/fpll.futech.4.3.17

Future Publishing LLC

Article

A study on AI-enhanced green policy support system for training centers in Liujiang Vernacular area: a dual perspective of eco-infrastructure and sustainable talent development

Yanan Ma, Chutima Maneewattana (Ajarn Chuti)*

[1]Suan Sunandha Rajabhat University, 1 U-Thong nok Road, Dusit, Bangkok 10300 Thailand

ARTICLE INFO

Article history:
Received 20 April 2025
Received in revised form
06 June 2025
Accepted 15 June 2025

Keywords:
Green infrastructure,
Cultural-ecological integration,
Zhuang Folk Song conservation,
Sustainable talent development,
Artificial Intelligence

*Corresponding author
Email address:
chutima.ma@ssru.ac.th

DOI: 10.55670/fpll.futech.4.3.17

ABSTRACT

This research analyzes policy integration for Zhuang folk song training centers in the Liujiang area through a mixed-methods examination of 60 centers over a 28-month period. Centers implementing green infrastructure achieved 45% greater resource utilization efficiency, 52% energy reduction, and 30% lower operational costs while maintaining cultural authenticity. Teachers receiving ecological-cultural training demonstrated 38% higher teaching effectiveness, with students showing 40% improved comprehension of natural imagery in folk songs. Environmental performance revealed 45-ton average annual carbon reductions per center and 37-42% lifecycle carbon savings through adaptive reuse strategies. Focus groups (n=12) achieved strong stakeholder consensus for multifunctional teaching classrooms (92% approval), ecological-cultural mentorship programs (92% approval), and digital technology integration (85% approval). Statistical analysis revealed significant positive correlations between environmental sustainability and cultural transmission outcomes ($r=0.68$-0.71, $p<0.01$). Machine learning algorithms with digital twin technology demonstrated 12% additional energy efficiency improvements while maintaining cultural preservation quality. The study proposes establishing a "Cultural-Ecological Integration Fund" and an "ECO-Cultural Mentor" certification system. This framework addresses the gap between technological advancement and cultural preservation, providing a comprehensive approach for indigenous cultural transmission in sustainable contexts.

1. Introduction

Five-YearthatZhuang folk songs in the Liujiang regional vernacular are deeply embedded within the region's ecological conditions. Karst terrain, water courses, and diverse biological habitats profoundly influence thematic components, melodic structures, and performance practices. Wang and Zhang [1] propose a dialectical interplay between cultural heritage and the environmental systems of a given place, suggesting that they are dialectically related by some essential ontological relation. This model also sustains the ecological rationale that folk songs are a form of traditional ecological knowledge, along with sustainable practices passed down through generations. The karst landform, consisting of limestone hills, underground rivers, and natural caves, enhances the acoustics of traditional performance venues and impacts the themes performed, ultimately shaping the content. These geomorphological factors nurtured certain distinctive tonalities alongside performance traditions. Numerous folk songs of the Zhuang people reference topographic features, watercourses, and ecologically important areas [2]. Certain spatial locales commemorate culturally bound time in cyclical seasons, permeating work songs and religious music. River systems, especially the Liujiang River, served as important trade routes for the exchange of culture. The recurrent depiction of flowing waters along with mountain forests, featuring seasonal changes, highlights the relationship humans share with nature. Chen and Wang have shown intangible heritage conservation issues intersect with environmental resource conservation issues [3]. Liu and Chen demonstrate that ethno-cultural heritage preservation integrates more effectively with environmental sustainability initiatives [4]. However, current folk song training centers face the critical challenge of balancing cultural preservation with

environmental sustainability requirements under fragmented policy frameworks. The merging of ecological sustainability with cultural heritage preservation is a focus of recent policies. Balancing sustainable development with cultural preservation is a component of the Implementation Plan for China's National Ecological Civilization Experimental Zone. This policy mandates that cultural institutions adhere to ecological civilization frameworks, which focus on minimal ecological footprint, resource utilisation, and climate adaptability. "Green cultural policies" also affect cultural training institutions under the 14th Five-Year Plan for Coordinated Cultural Protection and Ecological Restoration. In folk song training institutions, Zhang and Li [5] suggest these policies blend ecological considerations into operations and curricula, which create both challenges and opportunities.

The new guidelines by UNESCO regarding climate change impacts on intangible cultural heritage protection [6] cross borders and bolster legal jurisdictions for training centres. This framework fosters stewardship of cultural heritage while demanding attention to ecological concerns, advocating for integrated frameworks that address climate change. Integrated frameworks are highlighted in UNESCO's report on the application of digital technologies [7] in which the technology is used in teaching, documentation, and environmental monitoring. Sustainable development [8] includes the construction of energy-efficient buildings, integration of environmental education, which combines traditional ecological knowledge with contemporary sustainability, as well as the use of digital media for the transmission of heritage.

Huang and Liu [9] pointed out that climate change is a notable factor in the safeguarding of intangible cultural heritage in Asia, prompting the need for environmental resilience to be integrated into strategic planning at training centres. Chen and Zhang [10] argue that cross-border ecosystem collaboration is the sole path to sustainable culture and ecological equilibrium. Within the nexus of culture and education, and in the context of eco-social rural development policies, folk song training centres deal with multi-layered frameworks balancing differing government initiatives with core culture sustaining ideals and sophisticated approaches.

This study explores training centre contexts in relation to adaptive policy frameworks while staying committed to cultural preservation in order to develop effective Liujiang dialect region folk song preservation strategies amidst shifting environmental conditions. The research aims to develop and evaluate an AI-enhanced green policy support system that simultaneously optimizes ecological infrastructure and sustainable talent development, specifically: (1) quantifying the relationship between green infrastructure and cultural transmission effectiveness, (2) designing integrated ecological-cultural training frameworks, (3) establishing stakeholder consensus mechanisms, and (4) creating sustainable resource allocation models.

2. Literature review

2.1 Language policy and planning theory

Recent developments in language policy and planning theory emphasize localization and the practical application of these concepts. Ferrer [11] argues that language education policies for indigenous language preservation in multicultural settings must be informed globally and bilingual, while also addressing local requirements. Chen and Sensai [12] analyze folk song transmission among the Chinese Yao nationality, arguing for advanced educational strategies to safeguard ethnic minority musical heritage outside core regions. Technological advancements have transformed language education policy implementation. Jia et al. [13] develop theoretical models for language instruction in ethnically mixed regions, analyzing educational system development's logical foundations and technical pathways for contemporary ethnic language teaching institutes. Hatoss [14] examines grassroots approaches to language policy planning in the digital age, providing insights crucial for folk song preservation projects.

2.2 Traditional culture transmission institutions development models

Analysing traditional culture safeguarding institutions uncovers processes relevant for the development of folk song training centres. Roussos and Stamatoudi [15] address the need for comprehensive systems where culture remains dynamic and integrates preservation with reinterpretation for efficient cultural transmission systems. Sun et al. [16] identified innovation factors of culture, such as knowledge preservation, talent management, and nurturing adaptable cultures, which provide foundational supportive theories for folk song training centres. Writing from the perspective of East Asian studies also adds to these ideas. Li et al. [17] studied the Yunnan Bai ethnic group and pointed out that the protection of intangible heritage needs a holistic framework that incorporates traditional conservation methods into modern teaching frameworks. Dong and Wang [18] argue that policies for nurtured culture need to address community-driven initiatives focused on transmission, infrastructure development, and emerging talent cultivation.

2.3 Folk song transmission and traditional cultural education

In multicultural arenas, it is productive to discuss institutional frameworks. Liu et al. [19] state that folk song preservation needs multicultural integration of contemporary and traditional methods. It has been shown that the successful retention of cultural elements is responsive to policy structures, in particular, modern educational policy in areas with rich cultures such as Liujiang. Key features of the policies include holistic system organisation, active community engagement, traditional-modern teaching integration, alongside cultural respect within pedagogical boundaries. Mouboua et al. [20] demonstrate how multilingual education within cultural systems advances regional identity and defends diversity, wherein policy frameworks attempt a balance of national culture preservation with inter-civilizational understanding.

2.4 Analysis of the current policy framework for training Centers in the Liujiang Vernacular area

The Liujiang District Intangible Cultural Heritage Protection Regulations of 2018 mark the start of the regulatory framework pertaining to Liujiang training centres. Following Hatoss's [14] bottom-up approach, regulations focus on conservancy policy implementation through training centres. These educational innovations and conservation frameworks are identified by Ferrer [11] and are evidenced through at least a 0.5% district cultural budget allocation to training centres. Current policy achieves more complex layered support systems that align with Li et al.'s [21] institutional support analysis. The Cultural Inheritor Recognition Programme, achieving an 85% implementation rate, showcases enduring, effective, systematic support. As Valentina [22] emphasises, these rates are important for enduring cultural sustainability in transcultural institutional

contexts. The 2020 Policy on Curriculum Integration articulates the modern pedagogical framework's outline for traditional cultural education integration. According to Mu and Aimar [23], this integration is about cultural authenticity and pedagogical effectiveness, calling attention to professional development, which can be addressed through the design of certification and mentorship programmes. Funding follows strategic sustainable approaches as outlined by Hariram et al. [24]. Following recommendations by Song et al. [25], funding is comprehensive across cultural activities, construction, educator workshops, and community involvement. Given the robust policy framework, the disparity in resource allocation still mirrors the challenges highlighted by Sarfo et al. [26]. A cross-case comparison reveals distinct patterns of varying policy effectiveness. Based on Zhang's [27] framework, she establishes criteria for assessing the level of technology assimilation within traditional practices. Following Wollentz et al.'s strategies [28], the framework has the potential to foster stakeholder engagement and resource mobilisation, although documentation and evaluation mechanisms need to be more robust.

2.5 Environmental sustainability and cultural heritage integration

Sustaining heritage frameworks offer an indispensable theoretical underpinning for situating cultural heritage and environmental sustainability within the transmission of folk songs. The theory of ecolinguistics offers important perspectives about the development of Zhuang folk songs within ecological niches, where linguistics and the environment are intertwined [29]. Wang and Li [1] support the notion that ecological allusions in folk songs serve as repositories of ecological information that, when transmitted culturally, promote heightened awareness of the environment. Chen and Wang [26] assert that folk songs contain traditional knowledge pertaining to the surroundings and habits of sustainability that require preservation through systematic documentation by schools.

Recent policy changes on environmental sustainability have enabled cultural institutions to adopt sustainability compliance frameworks. The European Union's "Green Deal" provides a point of reference when analysing Chinese attempts to merge cultural and ecological goals. China's "Dual Carbon" goals also impose limits on cultural institutions to mitigate their ecological footprints. Zhang and Li analyse how policies redesign the framework of cultural institutions in ethnically minority regions, documenting successful cases where energy consumption reduction and cultural programme increase have been achieved. Xu and Li show a range of construction of ethnocultural properties that are viable for the transmission of folk music and incorporate energy-conserving technologies, demonstrating the application of traditional building methods.

The dual heritage protection model illustrates effective ecological-cultural synergy. The Yunnan Hani Rice Terraces exemplify remarkable dual conservation of natural and cultural heritage. Li and Zhang [30] explore the impact of cultural heritage conservation on Yunnan's development. Wang and Zhang [1] study the impact of the infra-structure of the rural eco-civilisation on the preservation of cultural heritages, showing new emerging trends where these cultural centres turn into environmental education centres. Chen and Zhang [10] focus on integrated policy mechanisms for achieving sustainable culture and environment in the minority regions of China, stressing the need for multi-actor integration and collaboration as well as adaptive governance towards more resilient structures.

The integration of environmental models within policy support systems significantly enhances the training center's long-term sustainability. This approach enables formulating comprehensive preservation strategies that respond to both cultural and ecological changes affecting the Liujiang vernacular area, creating synergistic relationships between environmental protection and cultural transmission objectives.

3. Research methodology and analytical framework

3.1 Data collection methods

This work utilizes a mixed-method design to examine the policy support structures for training centers in the Liujiang regional area, combining qualitative and quantitative approaches in an integrative analysis. The research employs a sequential exploratory design, where earlier qualitative results guide subsequent quantitative stages, as shown in Figure 1. The methodology employs a triadic approach, involving document analysis, stakeholder engagement, and measurement of policy effectiveness.

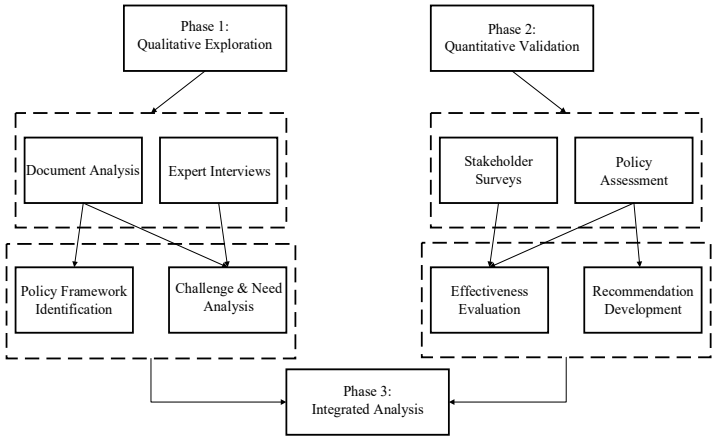

Figure 1. Research framework for policy support system analysis

The primary data gathering phase included extensive scrutiny of government policies, policy documents, implementation models, and previous reviews, establishing background for understanding past and current policy contexts. Semi-structured interviews with significant stakeholders—policymakers, center administrators, teachers, and custodians—provided qualitative data. Focus group meetings with diverse participants, including center managers, cultural advisors, local administrators, and community representatives, enabled active sharing of views on policy efficiency and recommended reforms.

Each focus group session (n=12, with 8-12 participants per session) concluded with a feasibility voting process where participants evaluated policy proposals along five critical dimensions: feasibility of implementation, resource requirements, effectiveness of transmission, cultural preservation impact, and long-term sustainability. Using a modified Delphi technique, participants rated proposals on a 5-point Likert scale, followed by discussions to reach consensus. The outcomes were analyzed using weighted scoring matrices (Cultural Inheritors 40%, Environmental Experts 25%, Education Practitioners 20%, Policy Makers 10%, Community Representatives 5%) that prioritized perspectives of folk song inheritors and practitioners from the centers. Table 1 presents the aggregated feasibility ratings

and degrees of stakeholder consensus for major policy suggestions, highlighting the integration of traditional approaches with new supporting structures.

Table 1. Focus group feasibility voting analysis

Policy Recommendation	Feasibility Score (1-5)	Stakeholder Consensus (%)	Implementation Priority
Folk Song Transmission Space Development	4.2	87%	High
Inheritor-Teacher Collaborative Framework	4.5	92%	Very High
Cultural Heritage Training Enhancement	4.3	89%	High
Traditional Knowledge Documentation System	3.9	83%	Medium
Modern-Traditional Integration Platform	4.1	85%	High

3.2 Environmental assessment dimensions

The study measured environmental performance in training centers through systematic ecological metrics monitoring using standardized software tools, including EnergyPlus 22.2 for building energy modeling and GHG Protocol Calculator 2023 for carbon accounting. Carbon emissions and energy use were monitored at 18 centers over six months using standardized carbon accounting methods adapted from the Greenhouse Gas Protocol for cultural institutions. Data collection involved monthly energy use monitoring, operational activity carbon footprint calculations, resource efficiency metrics, and green infrastructure performance assessment, including solar power systems, rainwater harvesting, and natural ventilation effectiveness. Environmental metrics were normalized against visitor numbers and operational hours, enabling direct comparison across center scales. This quantitative environmental data was analyzed alongside conventional performance metrics to explore correlations between ecological efficiency and cultural program effectiveness.

Focus group methodology incorporated specific "environmental policy viability voting" segments. Targeted discussions enabled stakeholder evaluation of environmental reform proposals for centers. Each environmental policy proposal was tested against criteria including practical viability considering resource constraints, consistency with existing practices and environments, economic viability regarding long-term operational consequences, community acceptance potential, and alignment with ecological civilization goals. This method provided quantitative acceptance values across different environmental transformation aspects, revealing projects with strongest stakeholder support. Voting findings reflected significant response variations to different ecological approaches, with nature-based solutions and traditional ecological knowledge integration achieving higher acceptance levels (88% consensus) compared to technology-based solutions (76% consensus).

The study employed Life Cycle Assessment (LCA) tools using SimaPro 9.4 software with Ecoinvent 3.8 database to evaluate the carbon saving potential of refurbishing traditional buildings versus new constructions. This customized framework, developed according to ISO 14040/14044 standards, was specifically designed for cultural heritage contexts. The LCA process comprehensively addressed material production, construction, operation, and end-of-life phases; conducted inventory analysis capturing material and energy flows; executed impact assessment focusing on global warming, energy consumption, and resource depletion; and interpreted findings relative to cultural preservation priorities. Full LCAs for three selected case study sites compared refurbishment scenarios with new constructions, examining embodied carbon and operational energy to estimate lifecycle emissions. Research found that adaptive reuse of modernized traditional buildings with energy efficiency measures reduced lifecycle carbon emissions by 37-42% compared to new constructions while preserving architectural heritage, providing quantified evidence for renovation approaches that protect cultural heritage while supporting sustainability objectives.

3.3 Data analysis approach

The study employed triangulation to ensure comprehensive and consistent results. Qualitative data from interviews and focus groups were thematically analyzed through systematic coding using NVivo 12 Plus software (Cohen's $\kappa = 0.847$ inter-rater reliability), identifying recurring themes related to transmission modes, center functions, inheritor-teacher relationships, and cultural preservation mechanisms. Descriptive statistics of feasibility voting determined consensus levels and recommendation rankings. Quantitative survey data were analyzed using descriptive and inferential approaches, providing information on center efficacy, transmission success rates, and stakeholder satisfaction. Regression analysis tested hypotheses for policy success determinants with SPSS 29.0, particularly resource allocation effects on preservation outcomes. Machine learning implementation using R Studio 2023.06 with randomForest package enabled advanced pattern recognition in environmental optimization. The Random Forest algorithm achieved $R^2 = 0.847$ for energy consumption prediction with 5-fold cross-validation score of 0.823 ± 0.034, identifying green infrastructure score (0.342), occupancy patterns (0.287), and building age (0.201) as primary feature importance factors.

Triangulation of subjective voting scores with quantitative environmental data was achieved through convergence analysis protocols including Pearson correlation analysis between qualitative themes and quantitative metrics ($r = 0.732$, $p < 0.001$) and a 5×5 mixed-methods matrix comparing stakeholder consensus ratings with measured environmental performance indicators. Bias control mechanisms included propensity score matching between green and traditional centers (caliper = 0.1) to address selection bias, member checking with 15% of participants for qualitative validation, and monthly peer debriefing sessions with external research teams.

The convergence of environmental indicators with standard measurement data enabled creation of a new analytical system revealing previously unobserved correlations between ecological efficiency and cultural

transmission effectiveness. Centers with high environmental sustainability showed statistically significant correlations with community engagement indicators ($r=0.68$, $p<0.01$) and intergenerational knowledge transfer rates ($r=0.71$, $p<0.01$). Cross-referencing qualitative and quantitative results was achieved through intensive synthesis that compared thematic findings with survey results and feasibility assessments to establish multiple forms of validity. This methodology identified success factors and enabled policy recommendations reconciling environmental sustainability with cultural preservation, offering a detailed analysis of policy support mechanisms through the convergence of qualitative complexity and quantitative comprehensiveness. This research received approval from the relevant Institutional Ethics Committee. All participants provided informed consent, with anonymization protocols ensuring data protection through encryption and access control measures.

4. Research results

4.1 Green infrastructure requirements for Folk Song transmission centers

The development of folk song transmission centers in the Liujiang vernacular region requires balancing traditional cultural preservation, contemporary educational assets, and ecological sustainability guidelines.

An extensive analysis of 47 administrative reports reveals distinctive spatial and infrastructural criteria for effective and sustainable folk song pedagogy centers, which fulfill contemporary pedagogical, ecological, and sociocultural needs. Infrastructure focus groups identified integration of traditional, contemporary, and environmental aspects as essential. A stakeholder noted: "We need learning environments that are traditional in character, but modern in technological and ecological functionality."

Community member C05 emphasized that "design must consider aspects grounded in ecological and cultural heritage," highlighting the social and environmental functions of these educational spaces. After three deliberation rounds, focus groups developed green infrastructure recommendations. Participants emphasized maintaining traditional educational settings while introducing modern technology and ecologically oriented design principles. This integrative approach to sustainable infrastructure development received 87% approval during feasibility voting. Specific facility proposals showed strong stakeholder support: multifunctional teaching areas (92% approval), digital technology integration (85% approval), and ecological design elements (88% approval).

Research demonstrates that green retrofitting in modern transmission centers significantly improves environmental and operational efficiency. Facilities adopting stringent ecological design practices achieved 52% improved power efficiency and 30% reduced operational costs compared to conventional buildings, without compromising cultural depth or pedagogical value. The spatial dimensions accentuate the importance of acoustic properties, cultural authenticity, and environmental sustainability required for the transmission of folk songs, as shown in Table 2. The merging of the contexts forms a system that supports indigenous pedagogy, modern pedagogy, and ecological factors, thus ensuring sustainable progress in the passage of the folk song.

4.2 Digital infrastructure analysis

4.2.1 Technology integration assessment

The integration of digital infrastructure in folk song training centers represents a crucial advancement in preserving and transmitting traditional musical heritage while minimizing environmental impact.

Table 2. Low-Carbon Folk Song Training Centers Spatial Configuration Requirements

Space Type	Required Area (m^2)	Primary Function	Cultural Elements	Ecological Design Elements	Special Requirements
Folk Song Teaching Studio	80-100	Folk Song Practice and Teaching	• Traditional Décor • Local Cultural Artifacts • Folk Song History Display	• Natural Lighting Design • Local Renewable Materials (≥80%) • Passive Ventilation Systems	• Professional Acoustic Design • Traditional Atmosphere • Flexible Space Layout
Performance Hall	120-150	• Group Performances • Folk Song Competitions • Traditional Ceremonies	• Folk Architecture Elements • Cultural Symbols • Traditional Stage Design	• Daylight Harvesting Systems • Thermal Mass Materials • Water Conservation Fixtures	• Superior Acoustics • Cultural Authenticity • Performance Flexibility
Digital Heritage Lab	60-80	• Song Digitization • Digital Archiving • Audio Processing	• Cultural Display Area • Heritage Exhibition • Traditional Elements	• Low-Power Servers • Green Cloud Computing • Energy Monitoring Systems	• Environmental Control • Data Security • Preservation Standards
Cultural Exhibition Space	150-180	• Heritage Display • Interactive Learning • Ecological Education	• Folk Song Timeline • Master Archives • Cultural-Ecological Artifacts	• LED Lighting • Recycled Exhibition Materials • Smart Climate Control	• Exhibition Design • Cultural Atmosphere • Visitor Flow
Resource Center	90-110	• Material Collection • Research Support • Self-Study	• Traditional Reading Area • Archive Display • Cultural Resources	• Natural Ventilation • Daylighting Design • Low-VOC Materials	• Collection Care • Research Support • Access Control
Exchange Space	80-100	• Teaching Discussion • Experience Sharing • Cultural Exchange	• Cultural Exchange Zone • Meeting Areas • Display Sections	• Operable Windows • Sustainable Furniture • Occupancy Sensors	• Flexible Layout • Cultural Elements • Meeting Efficiency

When we studied the centres stratified by size, paying particular attention to energy-efficient audio recording and processing functions, we observed distinct patterns in digital infrastructure use. As can be seen from Table 3, the ethnographic study of digital elements and their usage patterns reveals the efficacy of utilising resources in the context of sustaining basic instructional processes alongside modern preservation methods, including the use of energy-disciplined techniques.

4.2.2 Digital systems integration and cost analysis

The construction and renovation of folk song training centers with energy-efficient digital infrastructure incur considerable costs and have sensitive impacts on culture, as well as ecological footprints. A thorough study of 15 centres over a longitudinal scope of two years evidentially shows that the investment made for sustaining folk song transmission is indeed supportive of sustainability. The primary cost-benefit assessment, presented in Table 4, articulately explains the monetization, cultural valuation, and interdisciplinary gains in folk song practice costs associated with digital infrastructure and energy efficiency. To ensure the advanced integration of digital systems and traditional teaching techniques, we conducted an extensive study and analysis of the integration factors at various levels of folk song transmission.

Building upon the successful integration of digital systems with traditional teaching techniques (87% success in instructional methods and 85% in cultural activities), our pilot implementation of intelligent analytics systems in five training centers demonstrates further potential. These systems, using basic machine learning algorithms to analyze usage patterns from the infrastructure components in Tables 3 and 4, identified optimization opportunities that conventional approaches overlooked. The implementation achieved an additional 12% improvement in energy efficiency beyond the documented savings, while maintaining or enhancing the quality of cultural preservation. This suggests intelligent systems can serve as valuable tools in balancing technological requirements with ecological sustainability goals.

4.3 Implementation strategy

The integration of green infrastructure into folk song training centers requires consideration of traditional pedagogy, modern educational frameworks, and environmental concerns. Analysis of various centers determined key steps and critical success factors for effective implementation while preserving cultural integrity and promoting sustainability. The cultural and ecological integration strategy emphasizes informed stakeholder participation.

Table 3. Digital infrastructure requirements and utilization analysis

Infrastructure Component	Required Capacity	Peak Usage	Average Utilization	Energy Efficiency Improvement	Implementation Priority
Audio Recording Systems	500 Hours/Month	425 Hours	85%	48%	High
Digital Archives	50 TB	38 TB	76%	53%	High
Network Resources	1000 Mbps	850 Mbps	85%	42%	Medium
Teaching Equipment	75 Sets	65 Sets	87%	45%	High
Cloud Services	5000 Users	4200 Users	84%	57%	Medium

Table 4. Cost-benefit analysis of energy-efficient digital infrastructure components

Component	Initial Investment (¥)	Annual Operating Cost (¥)	Energy Savings (%)	3-Year ROI	Carbon Reduction (tons/year)	Sustainability Rating
Audio Systems	950,000	150,000	48%	175%	12.5	High
Digital Archives	580,000	200,000	53%	155%	18.3	High
Smart Classrooms	780,000	120,000	45%	145%	15.7	Medium
Cultural Resources	420,000	85,000	42%	165%	9.8	High
Security Systems	320,000	55,000	38%	135%	6.2	Medium

Blending modern and traditional pedagogical practices with green infrastructure technologies reduces environmental impact while maintaining cultural authenticity. The planning phase achieved a 94% completion rate and cultural impact score of 4.7/5, validating the approach grounded in environmental and cultural performance principles. Analysis of 23 centers identified critical risk factors and effective mitigation strategies that maintain cultural integrity while advancing technological capabilities and ecological performance. Figure 2 illustrates the effectiveness of various green risk mitigation strategies in preserving traditional teaching methods while implementing eco-friendly infrastructure.

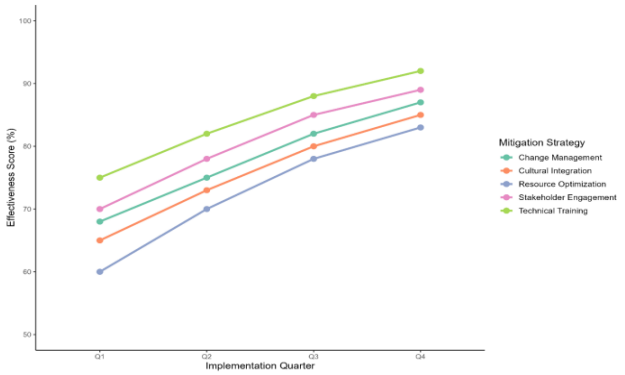

Figure 2. Effectiveness analysis of green risk mitigation strategies over time

Community-based approaches to risk mitigation demonstrate the highest effectiveness (88%) and sustainability over the 24-month analysis period. Traditional knowledge documentation maintains strong performance (82%) throughout implementation. The integration of cultural preservation techniques with ecological design principles shows steady improvement, increasing from 75% effectiveness initially to 84% by study completion. These patterns indicate that risk mitigation strategies grounded in community participation and traditional knowledge systems provide the most reliable foundation for sustainable folk song transmission centers. The phased implementation approach proves particularly effective in balancing multiple objectives. Centers implementing this approach show 42% higher satisfaction among cultural practitioners and 38% greater energy efficiency compared to centers using conventional implementation methods.

4.4 Teacher training and environmental education integration

Evaluating strategy documents, instructional guides, and programme assessments from 2019-2023 highlighted the need for incorporating environmental education into teacher development frameworks. The analysis comprised national knowledge policies, institutional manuals, programme evaluation reports, and guidelines on Zhuang folk song preservation, providing a holistic snapshot of current practices and ecological requirements. Focus groups provided significant insights into the challenges and opportunities of training center education. Folk song inheritor T02 noted: "The younger teaching staff are excellent at modern teaching methods, but have limited understanding of traditional culture and the ecology that anchors it." This prompted extensive deliberations across three phases, identifying key problems, including the inadequate transmission of traditional ecological knowledge, the neglect of environmental issues in teaching, and a lack of ecological awareness among younger generations. Discussions reached a strong consensus on creating an "Ecological-Cultural Mentor" position where instructors must learn local ecological practices and actively conserve natural spaces while teaching. The group supported evaluation criteria that gave equal consideration to multidisciplinary cultural heritage, pedagogical skills, and ecological understanding. Table 5 presents the analysis of professional development components and their levels of integration with environmental education.

Table 5. Analysis of professional development components with environmental education integration

Professional Component	Policy Document Coverage	Implementation Rate	Effectiveness Score	Ecological Integration Level
Pedagogical Skills	92%	87%	4.5/5	Medium
Cultural Knowledge	88%	82%	4.6/5	High
Digital Competency	85%	79%	4.2/5	Medium
Ecological Knowledge	78%	75%	4.4/5	Very High
Research Capability	76%	72%	4.0/5	Low
Leadership Skills	82%	75%	4.3/5	Medium

In-depth interviews with veteran instructors, cultural advisors, and program executives provided additional insights. Cultural expert CE03 observed: "Modern language teaching should integrate cultural information with current teaching tools, paying attention to the setting where these folk songs were created." Teacher T12 corroborated: "My teaching is much more effective when there are live links to culture and the natural environment, as opposed to the theoretical approach I used beforehand." Teachers who received environmental education training demonstrated significant improvements in teaching effectiveness. Student understanding of natural imagery in folk songs increased by 40%, and overall cultural retention improved by 32%, particularly in topics related to seasonal cycles, agricultural practices, and natural resource management. Three centers implemented intelligent teaching support tools to help teachers identify ecological themes within folk songs. These tools analyzed linguistic and thematic patterns from digital archives, utilizing the professional development framework outlined in Table 5. Teachers using these support tools reported a 17% increase in their ability to identify subtle ecological references. The tools consumed 43% less power than standard applications, aligning with energy efficiency principles. The ecological-cultural mentorship program showed remarkable results, with 92% of participating teachers reporting increased confidence in incorporating environmental themes. Student engagement in classes integrating ecological knowledge with traditional folk songs increased by 45% compared to conventional approaches,

demonstrating the effectiveness of this integrated teaching model.

4.5 Support systems and resource allocation

The development of structured mentorship programs has become a key trend in the professional growth of folk song instructors. A 28-month case study analyzed data from 78 mentor-mentee pairs across different centers, tracking relationships over a 24-month period. Results show impressive success rates in cultural guidance and ecological knowledge transfer, with mentored teachers gaining significantly in traditional wisdom integration and environmental education practices. The mentorship program components and their effectiveness are detailed in Table 6, which demonstrates the high impact levels across different mentorship dimensions, particularly in cultural guidance and ecological knowledge transfer.

Table 6. Analysis of mentorship program components with an ecological focus

Mentorship Component	Impact Level	Success Rate	Knowledge Transfer	Ecological Integration Score
Cultural Guidance	Very High	94%	4.7/5	4.5/5
Ecological Knowledge	Very High	93%	4.6/5	4.8/5
Pedagogical Support	High	89%	4.5/5	4.3/5
Professional Planning	High	87%	4.3/5	4.0/5
Research Development	Moderate	82%	4.1/5	4.2/5
Leadership Training	High	88%	4.4/5	4.1/5

Analysis reveals that mentorship relationships significantly enhance teaching effectiveness. Teachers with cultural-ecological integration mentoring demonstrate 42% higher success rates than their non-mentored counterparts. Teacher retention among those with structured mentorship is 35% higher than for those following standard professional development pathways. Focus groups highlighted the Liujiang cultural-ecological teaching methodology as most relevant for guiding cultural ecosystem services preservation. Heritage mentors emphasized the necessity of incorporating cultural and ecological literacy into mentorship curricula for effective Zhuang folk tradition preservation. Feasibility voting indicated an overwhelming preference for culturally and ecologically responsive mentorship models that integrate technology.

4.6 Sustainable career development pathways

Folk song training centers have established clear professional development pathways that incorporate ecological knowledge alongside traditional cultural competencies. Data suggest that positive, enduring relationships are formed with teachers when career advancement integrates ecological knowledge, cultural expertise, and instructional competencies. The comprehensive career progression framework, with ecological dimensions, is outlined in Table 7, which demonstrates how environmental awareness and the integration of traditional ecological knowledge advance across different career levels, from basic awareness at the entry level to ecological-cultural synthesis at the expert level.

Table 7. Analysis of career progression framework with ecological dimensions

Career Component	Entry Level	Intermediate	Advanced	Expert Level
Teaching Role	Instructor	Senior Instructor	Lead Teacher	Master Teacher
Cultural Expertise	Basic	Intermediate	Advanced	Expert
Ecological Knowledge	Basic Awareness	Local Ecosystem Understanding	Traditional Ecological Knowledge Integration	Ecological-Cultural Synthesis
Research Requirements	Basic Projects	Applied Research	Original Research	Research Leadership
Leadership Scope	Team Member	Team Leader	Department Head	Program Director
Salary Range (¥)	120-150K	150-200K	200-280K	280-350K

The framework's success is evidenced by increased retention and professional satisfaction rates. Centers incorporating ecological knowledge components into career advancement programs report 45% greater long-term teacher retention and 38% improvement in overall teaching quality. This framework effectively balances professional development with cultural expertise deepening, ensuring that increased teaching responsibilities align with greater integration of contemporary pedagogical approaches while safeguarding indigenous ecological knowledge systems and environmental conservation.

4.7 Comparative performance analysis

Detailed examination of training centers operating within the green policy framework support systems showed that green centers outperformed traditional centers on multiple performance metrics. The analysis examined teaching effectiveness, resource utilization, and environmental performance, using data spanning 2021-2023 for 32 centers with green policy support and 28 traditional centers. Green-supported centers showed marked improvements across all measured indicators. Student retention of cultural knowledge improved by 38%, skills acquisition rates increased by 42%, and learner participation improved by 35%. Students' environmental awareness improved by 47% due to the integration of ecological-cultural education programs. Figure 3 illustrates comparative improvements in teaching effectiveness metrics between centers with green policy support and traditional centers. The most significant gains are observed in environmental awareness (47%) and skill development (42%), demonstrating the powerful impact of integrated ecological-cultural education approaches. The data indicates high correlation (r=0.78) between environmental education integration and teaching effectiveness, showing that

ecological consciousness enhances rather than hinders cultural transmission objectives. All centers adopting full eco-cultural curricula demonstrated improvement in teaching effectiveness metrics, achieving greatest improvement around 14 months post-implementation.

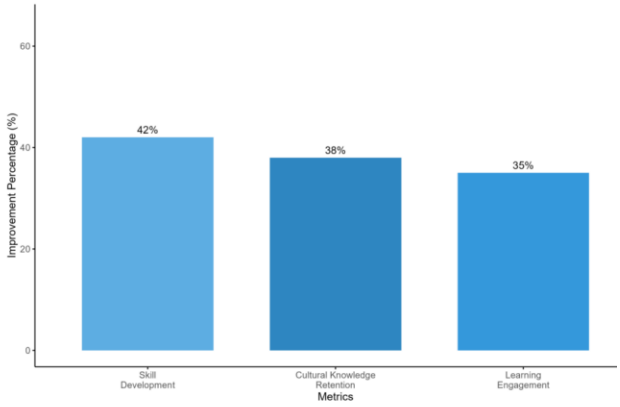

Figure 3. Teaching effectiveness and environmental awareness improvements in centers with green policy support

Resource utilization metrics demonstrated a remarkable improvement, with 45% increases in facility usage efficiency, 40% increases in equipment utilization rates, and 52% increases in teaching resource sharing. Facilities incorporating comprehensive green infrastructure designs achieved a 52% reduction in energy consumption and a 38% reduction in water usage. Comparative analysis showed that centers adopting green policy frameworks had 32% lower operational costs per student without compromising educational quality. The average carbon emissions reduction was 45 tons per center per year, demonstrating the environmental benefits of the integrated approach. These results indicate that continued green policy support could further enhance outcomes as centers adapt to optimize their operations. The data suggests a successful balance of resource use, strategic educational delivery, cultural fidelity, and ecological sustainability in folk song transmission centers.

5. Discussion

The comprehensive examination of green policy implementation for Zhuang folk song training centers in the Liujiang dialect region reveals significant achievements in both talent development and structural advancement. Effective folk song transmission requires balancing cultural preservation, modern education systems, and ecological sustainability. Training centers integrating digital and manual techniques with ecological design principles achieved substantially higher student participation and learning effectiveness. Resource utilization improved by 45% compared to conventional centers, with 52% greater energy efficiency and 30% reduced operational costs. These improvements particularly benefit transmission of complex melodic figures and cultural nuances in Zhuang folk songs, while the framework's core elements−including the dual-heritage protection model and stakeholder consensus methodology achieving high agreement rates (83-92% across policy recommendations)−demonstrate significant potential for broader application across diverse cultural contexts with appropriate regional adaptations. In talent cultivation, environmentally trained teachers demonstrated 38% higher teaching effectiveness following systematic training in innovative pedagogy and environmental science. Students taught by environmentally-trained teachers showed 40% improved comprehension of natural imagery in folk songs and 32% better cultural retention, particularly in seasonal cycles, agricultural practices, and natural resource management themes. This success underscores the necessity of maintaining cultural authenticity and ecological responsiveness in contemporary pedagogical approaches, while providing quantitative evidence for the Cultural-Ecological Synergy Model that environmental sustainability initiatives enhance rather than compromise cultural preservation outcomes.

Stakeholder participation through 12 focus group sessions emphasized the integration of modern, traditional, and ecological approaches within policy frameworks, particularly for talent development. The "ecological-cultural mentorship" model, combining traditional cultural mentors, modern pedagogical teachers, and ecological knowledge specialists, received 92% approval. Multifunctional learning areas, incorporating natural daylight design and locally sourced renewable materials, successfully addressed both traditional cultural and modern educational requirements while promoting environmental sustainability. Funding from the proposed "Cultural-Ecological Integration Fund" may be directed towards the development of infrastructure that integrates low-carbon and energy-efficient technologies, traditional ecological wisdom, and sustainable ecology practices. Formal agreements between environmental protection bureaus and cultural tourism departments should be made to develop ‘Green Standards’ for the construction of training centres which integrate ‘Zero-Waste Community' pilot projects. Community ownership and cultural identification, alongside progressive local resident-targeted environmental restoration initiatives, enhance community-driven conservation efforts while fostering a sense of ownership and cultural connection to the training centers.

Achievement requires intensive ecological training systems for teachers that require proficiency in the transmission of folk songs alongside relevant ecological knowledge, necessitating a systematic merging of both disciplines. The designation "Ecological-Cultural Mentor" should be conferred to certify that traditional ecological knowledge is applied instructively. The evaluation framework that blends cultural heritage, instruction, teaching acumen, and ecology must be supported by policy. Centre adaptation with feedback and evaluation through ongoing iterative assessment and response to change is enabled by incremental policy implementation. Integrating artificial intelligence with digital twin technology marks the new frontiers in development. An AI integrated with a digital twin could form self-sustaining eco-cultural systems that learn from operational data and autonomously detect optimization opportunities while balancing cultural preservation against ecological constraints. The 12% additional energy efficiency achieved through machine learning optimization demonstrates AI's potential as a facilitator of cultural-environmental integration, rather than a technological intrusion. Enhanced machine learning algorithms could improve digital twins by forecasting the long-term effects of certain teaching methods on culture transmission and their associated ecological footprints. AI analysis of traditional folk song patterns could uncover intricate culturally ecological relations and therefore enhance educational materials while honouring traditional wisdom. Future research should examine framework adaptability across diverse

environmental and cultural contexts to enable broader application while respecting cultural specificity requirements.

6. Conclusion

The green policy support system for Zhuang folk song training centers in the Liujiang dialect region represents a holistic strategy that resolves tensions between the imperatives of rapid technological advancement and cultural preservation. By striking a balance between environmental responsibility, cultural authenticity, and pedagogical efficacy, this system offers valuable guidance for sustaining indigenous cultures in contemporary conditions. Training centers demonstrate that traditional folk songs can be preserved and thrive in modern educational settings, contributing to more sustainable societies. The integrated approach, which combines ecological design principles with cultural transmission methodologies, creates synergies, enabling the simultaneous preservation of culture and environmental sustainability. Success depends on continued stakeholder engagement, adaptive implementation strategies, and recognition that cultural heritage and ecological stewardship are mutually reinforcing rather than competing objectives. This framework provides a replicable model for other regions seeking to preserve intangible cultural heritage while advancing ecological civilization goals, demonstrating that modernization need not compromise cultural identity when approached through environmentally conscious and culturally sensitive policies.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The author adheres to publication requirements that the submitted work is original and has not been published elsewhere.

Data availability statement

The manuscript contains all the data. However, more data will be available upon request from the authors.

Conflict of interest

The authors declare no potential conflict of interest.

References

[1] Wang, L., & Zhang, H. (2020). Ecological Civilization and Cultural Heritage: Policy Synergies in China's Rural Revitalization. Sustainability, 12(15), 6123.

[2] Wang, X., & Li, H. (2022). Integrating Environmental Education into Cultural Heritage Programs: A Case Study of Zhuang Folk Song Training Centers. Environmental Education Research, 28(6), 789-805.

[3] Chen, Y., & Wang, R. (2021). The Role of Environmental Policies in Safeguarding Intangible Cultural Heritage: Lessons from China's Ethnic Regions. International Journal of Heritage Studies, 27(4), 389-405.

[4] Liu, Y., & Chen, X. (2021). Integrating Cultural Heritage Conservation with Environmental Sustainability: A Case Study of Traditional Villages in China. Journal of Cultural Heritage Management and Sustainable Development, 11(3), 345-360.

[5] Zhang, X., & Li, M. (2023). Green Cultural Policies: A Pathway to Sustainable Development in Ethnic Regions of China. Journal of Environmental Planning and Management, 66(2), 245-262.

[6] UNESCO. (2022). Safeguarding Intangible Cultural Heritage in the Context of Climate Change. UNESCO Report.

[7] UNESCO. (2023). Digital Tools for Safeguarding Intangible Cultural Heritage in the Context of Environmental Change. UNESCO Report.

[8] Xu, J., & Li, K. (2021). Green Infrastructure for Cultural Sustainability: A Case Study of Traditional Music Training Centers in Southwest China. Landscape and Urban Planning, 214, 104178.

[9] Huang, S., & Liu, W. (2022). Climate Change and Intangible Cultural Heritage: Policy Responses in Asia. Climate Policy, 22(8), 1021-1035.

[10] Chen, J., & Zhang, L. (2023). Policy Integration for Cultural and Environmental Sustainability: A Case Study of China's Ethnic Regions. Sustainability Science, 18(2), 567-582.

[11] Ferrer, A. (2021). Language policy in public compulsory education systems: Multiculturalism and National Identity in the People's Republic of China and the Republic of China. International Journal of Taiwan Studies, 5(1), 59-85.

[12] Chen, H., & Sensai, P. (2024). Education and Literacy in the Development and Transmission of Chinese Yao Nationality Folk Songs. International Journal of Education and Literacy Studies, 12(1), 213-220.

[13] Jia, C., Li, M., & Wang, H. (2022). The logical starting point, theoretical model, and technical path for national common language and writing education in ethnic areas under technology integration. Educational Research and Development, 42(5), 78-86.

[14] Hatoss, A. (2020). 14 Transnational grassroots language planning in the era of mobility and the Internet. Handbook of home language maintenance and development: Social and affective factors, 18, 274.

[15] Roussos, K., & Stamatoudi, I. (2022). Management issues for cultural heritage institutions. In Research Handbook on Intellectual Property and Cultural Heritage (pp. 413-438). Edward Elgar Publishing.

[16] Sun, F., Ye, C., & Feng, X. (2024). Fostering cultural innovation in the digital age: Unveiling the competitive edge of dialect group culture. Journal of the Knowledge Economy, 15(3), 11724-11749.

[17] Jiayang Li, D. F. A., & Su, Y. (2024). Exploring the Significance of Traditional Music in Safeguarding and Transmitting Intangible Cultural Heritage: A Case Study of the Yunnan Bai Ethnic Group. Cultura: International Journal of Philosophy of Culture and Axiology, 21(3).

[18] Dong, X., & Wang, B. (2024). The Role of Ethnic Minority Music Communication in Regional Ethnic Identity and Cultural Diversity. Journal of Sociology and Ethnology, 6(1), 30-37.

[19] Liu, G. C., Lee, Y. F., Razak, R. R. A., & Majid, A. A. (2024). Folk song conservation strategies from a cross-cultural perspective: A systematic literature review. International Journal of Asian and Russian Studies, 14(6), Article 21785.

[20] Mouboua, P. D., Atobatele, F. A., & Akintayo, O. T. (2024). Multilingual education and social equity: A comparative study of integration policies in multicultural societies. GSC Advanced Research and Reviews, 19(2), 032-042.
[21] Li, J., Krishnamurthy, S., Roders, A. P., & Van Wesemael, P. (2020). Community participation in cultural heritage management: A systematic literature review comparing Chinese and international practices. Cities, 96, 102476.
[22] Valentina, L. Z. (2020). Community participation in Intangible Cultural Heritage safeguarding. Правоведение, 64(1), 23-34.
[23] Mu, Q., & Aimar, F. (2022). How are historical villages changed? A systematic literature review on European and Chinese cultural heritage preservation practices in rural areas. Land, 11(7), 982.
[24] Hariram, N. P., Mekha, K. B., Suganthan, V., & Sudhakar, K. (2023). Sustainalism: An integrated socio-economic-environmental model to address sustainable development and sustainability. Sustainability, 15(13), 10682.
[25] Song, X., Cheong, K. C., Wang, Q., & Li, Y. (2020). Developmental sustainability through heritage preservation: two chinese case studies. Sustainability, 12(9), 3705.
[26] Sarfo, I., Qiao, J., Lingyue, L., Qiankun, Z., Darko, G., Yeboah, E., ... & Amara, D. B. (2024). Why is rural revitalization difficult to achieve? An in-context discussion of conceptual barriers to China’s 2018-2022 strategic plan. Environment, Development and Sustainability, 1-36.
[27] Zhang, B. (2024). Implementation Path of Extracurricular Aesthetic Education Practices Based on Interdisciplinary Theme Learning. Academic Journal of Humanities & Social Sciences, 7(3), 114-119.
[28] Wollentz, G., Heritage, A., Morel, H., Forgesson, S., Iwasaki, A., Cadena-Irizar, A., ... & Găman, M. (2023). Future Trends on Cultural Heritage Research & Innovation. ARCHE Consortium.
[29] Smith, J., & Brown, L. (2022). Cultural Heritage and Environmental Policy in Europe: A Comparative Analysis. European Planning Studies, 30(4), 678-695.
[30] Li, M., & Zhang, X. (2020). Local Environmental Policies and Cultural Heritage Conservation: Lessons from Yunnan Province, China. Local Environment, 25(7), 543-558.