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The Compilation and Application of the Digitalized Manual for Teacher Collaboration in Green Environmental Protection Courses

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Abstract: *Under the dual background of the "dual carbon" goal and the digital transformation of education, green environmental protection courses face practical challenges such as poor inter-grade coordination, insufficient teacher collaboration efficiency, and fragmented teaching resources in cross-grade collaborative education. Focusing on the preschool and primary school stages, by developing a digital teacher collaboration manual, this study systematically analyzes the technical obstacles, collaboration resistance, and content adaptation problems encountered during its application, and proposes a three-dimensional optimization path of "layered training - tool iteration - institutional guarantee" to promote the transformation of digital tools from "static text" to "dynamic ecological carrier". The findings offer both theoretical underpinnings and practical insights for establishing a collaborative-driven paradigm in green education, and have significant academic value and practical significance.*

Keywords: *Digitalization; Green Environmental Protection; Teacher Collaboration; Cross-Grade Education; Preschool-Primary School Transition*

1. Introduction

In the era of deep integration of the "dual carbon" strategy and the digital transformation of education, green environmental protection education has become a key path to implement the concept of sustainable development and cultivate the ecological literacy of future citizens. However, the current implementation of green environmental protection courses across different educational stages, especially in the preschool and primary school stages, faces many challenges. Focusing on the collaborative education practice of green environmental protection courses in the preschool and primary school stages and exploring the empowerment path and optimization plan with the digital teacher collaboration manual as the tool carrier is of great significance.

2. Research Background and Significance

2.1 Policy-driven: Integration of Ecologicalization and Digitalization in Education

Driven by the "carbon neutrality" goal, green and low-carbon education has become an important part of the national strategy. The "Action Plan for Carbon Peak Before 2030" clearly requires "integrating the concept of green and low-carbon into the education system". The preschool and primary school stages are the critical periods for cultivating ecological literacy, and the collaborative implementation of courses directly affects the formation of citizens' environmental awareness. At the same time, "China's Education Modernization 2035" emphasizes the digital transformation of education and promotes the construction of intelligent teaching and management platforms, providing technical support for green course collaboration. The "Compulsory Education Curriculum Plan (2022 Edition)" lists "interdisciplinary theme learning" as a compulsory content. Green courses, due to their interdisciplinary nature, have opportunities for development, but they also face the real challenges of disciplinary barriers and academic stage fragmentation [1].

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2.2 Practical Challenges: Structural Dilemmas in Collaborative Education

The practice of green course collaboration faces three contradictions: academic stage gap, manifested as a lack of gradient connection between the emphasis on sensory experience in kindergartens and the focus on rational exploration in primary schools; insufficient teacher collaboration due to physical space isolation, work time differences, and teaching concept conflicts, making cross-academic-stage collaboration difficult to deepen; resource dispersion, with existing teaching resources being scattered, having strong universality, and lacking systematic and stage-adapted digital content, which restricts the collaborative effect.

2.3 Research Value: Theoretical Innovation and Practical Exploration

By constructing a digital teacher collaboration manual, integrating collaborative governance theory, technology acceptance model, and sustainable development education (ESD) concepts [2], forming a "technology-education-ecology" integration framework, it compensates for the lack of combination of tools and mechanisms in existing research. At the practical level, the manual incorporates real-time collaboration, intelligent recommendation, and cross-academic-stage evaluation functions, aiming to solve the problems of "difficult collaboration" and "fragmented resources". At the policy level, the results provide a basis for cross-disciplinary and cross-academic-stage resource sharing, support local formulation of green course collaboration guidelines, and promote the deep integration of digitalization and green education. Therefore, through the compilation and application of the digital teacher collaboration manual, a new paradigm of cross-academic-stage green environmental education has been constructed, with significant academic value and practical significance.

3. Challenges in Application

3.1 Technical Obstacles: Digital Literacy Disparity and Functional Disconnection of Tools

The effective application of digital collaborative manuals is predicated on teachers having a certain level of digital literacy. However, there are still significant shortcomings in practice, particularly manifested in the skill gap among senior teachers and the design flaws of the tools.

Teacher digital literacy can be divided into three levels: technical operation, resource integration, and collaborative innovation [3]. According to a recent survey on teacher digital literacy (2024), only 30% of teachers over 45 years old can proficiently complete basic operations such as online collaboration and resource retrieval, and less than 15% can apply data analysis to assist teaching. The skill gap mainly stems from three aspects: first, generational digital native differences, where senior teachers have a resistant attitude towards digital teaching tools and even view them as an additional burden; second, training content and form lag behind, with a "one-size-fits-all" approach to technology indoctrination, failing to combine task-driven training with green curriculum design; third, the transmission of technical anxiety, where teachers' self-efficacy decreases when encountering compatibility and permission setting issues during operation, ultimately choosing to abandon the use.

In addition, there are also problems with tool adaptability. Current mainstream collaboration platforms (such as Feishu, DingTalk) are disconnected from teachers' actual working scenarios. For example, the development of the manual requires frequent use of multi-person annotation and version backtracking functions, but most platforms only support basic text editing and cannot handle complex operations such as embedding mind maps and collaborative editing of formulas, resulting in layout errors. A survey conducted in pilot schools revealed that over 70% of teachers encountered insufficient format support when trying to input a cross-grade activity plan titled "Campus Carbon Footprint Calculation" into the manual. They were forced to resort to multiple separate files for storage and sharing, which severely compromised resource integrity and collaboration fluency.

Moreover, the classification of the resource library is mostly based on administrative logic (such as "municipal resources"), rather than teaching logic (such as "low-carbon experiments for third-grade primary school students"), making it difficult for teachers to filter and directly reducing the willingness to use.

3.2 Collaborative Resistance: Spatial and Temporal Barriers and Lack of Motivation Mechanism in Cross-Disciplinary Collaboration

The collaboration between preschool and primary school teachers is essentially the coupling of different educational ecosystems. However, in practice, it faces dual resistances of schedule conflicts and lack of motivation [4].

First, in terms of temporal and spatial collaboration, kindergarten teachers work in a "half-day concentrated" mode, with the main teaching period being 9:00 to 11:30 in the morning; primary school teachers, on the other hand, are fragmented in their working time due to the "40-minute class, break management" system. This time rhythm difference leads to a participation rate of real-time collaboration below 20%, and collaboration mostly relies on asynchronous tools (message boards, emails). Studies show that in cross-disciplinary lesson preparation, the "demand-feedback" closed loop takes an average of 4.7 interactions, with an efficiency 63% lower than real-time communication, and is prone to semantic misunderstandings, such as misinterpreting "natural observation activities" as "experimental report tasks".

Second, in terms of the motivation mechanism, cross-disciplinary collaboration lacks long-term arrangements for shared benefits and shared responsibilities [5]. The current teacher evaluation is centered on intra-disciplinary achievements (such as the rate of behavioral habit formation in kindergartens, science class scores in primary schools), and green curriculum collaborative achievements cannot be included in the assessment. Interviews with participating teachers for this study uncovered a representative case: a primary school science teacher meticulously designed a "Seed Growth Observation" project to connect with kindergarten activities. However, because this collaborative outcome was not recognized in her personal professional title evaluation or performance assessment, the project proved difficult to sustain, and her motivation for subsequent similar collaborative designs significantly diminished.

At the same time, teachers need to invest additional time in studying the curriculum standards' alignment for the corresponding grade levels (such as the "Guidelines for the Development of Children Aged 3-6" and the "Science Curriculum Standards"), but such implicit costs are not included in the workload, resulting in teachers' motivation remains primarily extrinsic and task-oriented and lacking the intrinsic motivation for continuous innovation.

3.3 Content Adaptability: Cognitive Discontinuity and Insufficient Intelligent Support

Green curriculum knowledge has a spiral ascending characteristic [6], such as "Understanding Plants - Ecological Functions - Biodiversity", but there are problems of ambiguous cognitive gradients and the absence of dynamic mechanisms in the development of the manual [7].

From the perspective of cognitive laws, young children mainly rely on concrete thinking and need to establish environmental protection awareness through sensory experiences (such as touching leaves, observing ants); primary school students enter the stage of concrete operation and can deepen their understanding through experimental exploration (such as measuring water quality, calculating classification accuracy). The research found that 65% of the collaborative cases have phenomena of knowledge repetition or discontinuity. For example, the "garbage classification" theme in kindergartens focuses on color games, while in primary schools it focuses on the principle of circulation, lacking intermediate transitional design (such as family classification diaries); in one specific collaborative unit, due to the lack of communication, primary school teachers repeated teaching the content of "plant growth", leading to a decline in students' interest. It was only after utilizing the manual's "knowledge link point" tagging function that both teachers clearly identified the content overlap and redesigned a spirally ascending teaching path from "sensory recognition" to "experimental recording"; in some cases, due to the lack of communication, primary school teachers repeat teaching the content of "plant growth", resulting in a decline in students' interest. The root of the problem lies in the traditional manuals' reliance on static text, which cannot visually present the vertical gradient and horizontal correlation of knowledge points, making it difficult for teachers to quickly locate the collaborative entry point.

In terms of digital support, the system lacks intelligent grading and dynamic adaptation capabilities. Teaching resources are not labeled with cognitive levels (such as perception, understanding, application levels), and need to be manually screened by teachers; resource updates rely on administrators' manual uploads, and cannot be automatically optimized and recommended based on teaching feedback (such as common student errors, search keywords of teachers). In addition, green courses have strong timeliness and need to be updated along with environmental policies and local ecological events, but the existing tools lack a dynamic push mechanism, resulting in teachers using outdated case content.

4. Optimization Suggestions

To address the aforementioned technical, collaboration, and content adaptation issues and facilitate the transformation of the digital handbook from "usable" to "easy-to-use and willing-to-use", this study has established a three-pronged optimization system of "layered training - tool iteration - institutional guarantee". This system aims to comprehensively address the key bottlenecks in collaborative practice through precise teacher development paths, intelligent technical support platforms, and long-term institutional operation mechanisms, providing a solid foundation for the construction of a cross-grade green curriculum education community.

4.1 Layered Training: Establish a digital literacy cultivation system that integrates "competence - scenario - resources"

To systematically enhance teachers' digital literacy in green curriculum collaboration, it is necessary to fundamentally innovate the training mechanism and establish a three-dimensional training system based on competence stratification, with real teaching scenarios as the driving force and digital resources as the support.

Firstly, implement a stratified training mechanism based on competence diagnosis. By leveraging standard tools such as the "Teacher Digital Literacy Micro Certification System", the mechanism can construct a teacher digital literacy capability profile, divide teachers into "basic - advanced - innovative" three levels, and design differentiated training plans. For teachers at the basic level (predominantly senior teachers), focus on the initial training of technical operations and anxiety relief, and through one-on-one mentorship pairing and scenario simulation training, strengthen the basic platform operation and common fault handling capabilities. For teachers at the advanced level (predominantly middle-aged and young teachers), promote the deep integration of tools and green courses, and the training content covers collaborative editing skills, cross-grade knowledge integration strategies, and project-based collaborative task design. For teachers at the innovative level (predominantly key teachers), focus on cultivating their data analysis and intelligent technology application capabilities, encourage the use of AI-assisted teaching design and educational action research, and form replicable collaborative innovation cases.

Secondly, build a training resource library deeply integrated with real teaching scenarios. The resource types should include three categories: micro-video tutorials, categorized by typical collaborative scenarios (such as cross-school resource sharing, asynchronous collaborative lesson planning, etc.), highlighting key steps and error analysis; standardized task templates, such as cross-grade knowledge connection tables, collaborative activity design flowcharts, etc., supporting teachers to fill and share online collaboratively; excellent practice case packages, presenting complete collaborative teaching design, implementation process, and details of digital tool application, accompanied by exemplary annotations and usage suggestions.

Finally, establish a dual assessment mechanism combining process and outcome. The process assessment relies on platform records of teacher behavior data, such as resource usage rate, collaboration participation frequency, etc., generating a digital literacy development map; the outcome assessment is conducted through semester results exhibitions, empirical material reviews, etc., selecting outstanding collaborative teams and cases, promoting experience promotion and paradigm diffusion.In the pilot practice in Fuzhou, a micro-certification-based incentive mechanism was preliminarily established. For instance, a senior kindergarten teacher who was initially resistant to digital tools received a "Digital Collaboration Rising Star" badge from the platform after completing the "Basic Operations Module" training and successfully organizing an online collaborative lesson preparation session. Her case was included in the resource library, which significantly boosted her confidence and motivation for further exploration.

4.2 Tool Iteration: Build a new-generation support platform with "intelligent collaboration" and "time-space integration" as the core

The core competitiveness of the digital collaborative handbook lies in whether its technical architecture can effectively support cross-grade and cross-context collaborative needs. The platform function design should focus on three dimensions: temporal coordination, resource matching, and process optimization.

In terms of temporal coordination, an intelligent schedule management module should be developed. The realization of this function relies on the openness of data interfaces of the school's educational administration system. In practice, the problem of data silos needs to be prioritized to be solved, supporting teachers to visually mark collaborative time periods, and the system automatically identifies common free time and recommends the optimal meeting arrangement. At the same time, the module can provide asynchronous collaboration support functions, such as multimodal message boards, voice annotations, etc., to alleviate the collaboration obstacles caused by differences in schedules. This module can also be connected with each school's educational administration system to automatically avoid school-level activity conflicts and enhance the feasibility and participation of collaborative plans.

In terms of resource matching, an AI-enhanced recommendation engine should be constructed based on the green curriculum knowledge graph [8]. All teaching resources need to be labeled with cognitive levels, grade-appropriateness, and connection points, and personalized resource should be achieved based on user behavior data (such as search records and collaboration history). After introducing this mechanism into the pilot platform, when a third-grade teacher uploaded a teaching design for a "Home River Pollution Survey", the system automatically recommended related kindergarten sensory activity videos on "Water Characteristics" and a fifth-grade inquiry-based learning plan on "Water Resource Cycle and Governance", highlighting key knowledge connection points. This effectively supported teachers in cross-grade curriculum planning.The system also needs to introduce a dynamic update mechanism to automatically capture the latest policies and cases from authoritative platforms, ensuring the timeliness and scientificity of teaching content.

In terms of process optimization, a collaborative quality analysis tool should be developed to monitor and analyze key indicators such as communication efficiency, resource reuse rate, and emotional attitudes during the collaborative process. This tool can identify collaboration bottlenecks, warn of potential conflicts, and provide teachers with optimization suggestions, such as recommending shorter meeting times, adjusting communication methods, or introducing mediators for coordination, thereby improving collaborative efficiency and quality.

4.3 Institutional Guarantee: Build a long-term support mechanism of "incentives, organization, and resources" in a tripartite form

The sustainable application of the digital collaborative manual cannot rely solely on technology or individual behavioral changes; it must receive systematic support at the institutional level. Efforts should be made from three aspects: evaluation mechanisms, organizational design, and resource guarantee, to build a positive ecosystem for cross-grade collaborative education.

First, improve the cross-grade collaborative evaluation system. The system will add a "collaborative education" dimension to the teacher performance assessment, clearly defining quantitative indicators such as the activity level of the manual usage, joint lesson plan development, and the effectiveness of students' cross-grade literacy improvement. For example, a pilot district's plan explicitly stipulated that the time teachers spent on cross-grade collaborative lesson preparation could be counted as 1.5 times the standard hours for continuing education. Outstanding collaborative course cases produced could serve as significant achievements in professional title evaluations. This institutional design directly transformed the "implicit costs" of collaboration into tangible benefits, providing solid motivational incentive for teacher participation.At the same time, implement a diversified evaluation mechanism, including self-evaluation, peer review, expert evaluation, and student feedback, to ensure that the evaluation results are comprehensive and objective. For outstanding teams and individuals, they should be given preferential treatment in terms of professional title evaluation, commendation and rewards, and support from special funds for participation in high-level teaching research activities.

Second, innovate the cross-grade teaching organization model. The regional education authority should take the lead in establishing a "green curriculum collaborative development community", integrating 3-5 kindergartens and primary schools as collaboration units, implementing a dual leader system (school and kindergarten leaders), and regularly organizing joint teaching research meetings. The regional education authority should promote regular collaborative lesson preparation and teaching demonstration classes, create a combination of physical and virtual teaching spaces, and strengthen the main role of front-line teachers in curriculum design and implementation.

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Third, improve the resource support system. The system can set up a special fund for platform function customization, teacher training, and facility support; clearly include collaborative lesson preparation time in the teacher workload assessment and provide necessary time and space guarantees; form a cross-disciplinary expert team covering education theory, information technology, and ecological disciplines, to provide precise professional support and consultation guidance for teachers.

Through the above institutional design, a virtuous cycle mechanism of "technology empowerment to support teacher development, teacher development to drive curriculum innovation, and curriculum innovation to feed back to technology iteration" will be ultimately formed.

5. Conclusion

The development of the digital empowerment handbook for green environmental protection course teachers' collaboration is an important practice in responding to the deep integration of educational ecology and digital transformation. This study identified that the core contradiction faced by cross-grade collaboration stems from the tripartite interaction dilemma among technological tools, teachers' capabilities, and institutional environment. Based on this, it proposed a systematic path of "layered training - tool iteration - institutional guarantee", which effectively alleviated problems such as insufficient digital literacy of teachers, low collaboration efficiency, and poor content integration, and promoted the transformation of digital tools from "static text" to "dynamic ecological carriers".

This handbook and its supporting system not only provide a promotable implementation model for cross-grade collaborative education in green courses, but also the integrated training model of "ability - scenario - resource", the tool development strategy of "time-space adaptation, intelligent collaboration", and the three-dimensional institutional framework of "incentive - regulation - support" constructed therein provide references for other interdisciplinary and cross-grade educational collaboration projects. Future research should further integrate new technologies such as artificial intelligence and virtual reality, expand application scenarios such as virtual ecological experiments and dynamic resource push, continuously improve the "technology empowerment - teacher development - curriculum innovation" cycle mechanism, promote green education to achieve a fundamental transformation from knowledge imparting to quality cultivation, and provide a solid foundation for comprehensively enhancing national ecological literacy and the high-quality development of education.

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