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Research on the Spatial Design of Smart Classrooms in Rural Small-Scale Schools

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Abstract: *Against the backdrop of China's rural revitalization strategy, existing small-scale rural schools face core challenges including rigid spatial configurations, outdated and potentially hazardous building materials, and a significant erosion of distinctive regional cultural identity. Leveraging national policy support (e.g., the Rural Development Action Plan Implementation Scheme) and the enabling potential of "Internet + Education" technologies, this study proposes "Smart Classroom Space Design for Rural Schools" as a solution to overcome the limitations of conventional classrooms. The research addresses teacher shortages through flexible, convertible composite spatial layouts; enhances environmental safety and reinforces local cultural belonging by innovatively integrating regional building materials with modern construction techniques; and embeds distinctive cultural identity by interpreting vernacular context through architectural form and decorative language, transforming classrooms into living carriers of cultural heritage. Centered on the principles of "spatial composability, material regionalization, and cultural explicitness," this smart classroom approach not only provides essential physical infrastructure for diverse pedagogical models but also serves as a critical pathway to bridge the urban-rural education gap and invigorate endogenous cultural vitality within rural communities. By efficiently integrating resources and revitalizing local wisdom, it demonstrates dual practical value in advancing educational equity and driving sustainable rural revitalization.*

Keywords: *Rural Classroom; Smart Classroom; Space Creation; Regional Characteristics*

1. Introduction

Education is the soul of the countryside. Educational revitalization plays a vital role in rural revitalization. Achieving the goals of rural revitalization requires consolidating and expanding the achievements of rural education reform, empowering rural revitalization through the revitalization of rural education [1].

Currently, the spatial models, functional facilities, and other aspects of rural schools struggle to meet the requirements of rural education reform goals, with spatial environment issues being particularly critical. Addressing how to design and optimize the spatial environment of rural schools to meet the new demands arising from the reform and development of rural education is therefore a major challenge urgently needing resolution in the current context of rural education revitalization. To address this challenge, this paper proposes strategies for constructing smart classroom spaces in rural areas. The term "smart" here embodies not only technological aspects, such as the improvements and influences of "Internet + Education" on teaching methods, but also represents a distinct spatial wisdom compared to traditional classrooms in terms of their spatial configurations.

2. Current development status and main problems of rural classroom spaces

2.1 Current development status of rural classroom spaces

Between 1976 and 2016, a total of 916,000 primary schools disappeared in China, most of which were rural primary schools. The "closure and merger of schools" policy emerging in the mid-1990s accelerated this disappearance of rural primary schools, aiming to optimize and integrate educational resources and improve economies of scale[2].Due to demands stemming from geographical environments, culture, education, and other factors, the surviving rural schools mostly adopt

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"small-class" teaching approaches, sometimes reduced to the scenario of a single classroom, one teacher, and one student. Currently, optimization strategies and research methods specifically targeting the spatial environments of these rural classrooms are relatively scarce. Therefore, improving and optimizing rural educational spaces from the perspective of spatial design represents one of the strategies and methods for rural education revitalization.

2.2 Main problems facing the development of rural classroom spaces

2.2.1 Monotonous spatial models

Limited by the number of teachers and students, the spatial models of current rural classrooms are largely singular, only capable of meeting basic teaching needs. Diverse teaching experiences such as discussion and recreation are constrained by this spatial monotony. Different teaching methods necessitate different spatial models, and the diversification of teaching methods can significantly enhance teaching effectiveness. Consequently, to effectively enrich teaching modes requires changing this singular spatial model.

2.2.2 Outdated spatial materials

The materials used in the construction of rural classroom spaces are often simple, primitive, or, in many impoverished areas, limited to vernacular building materials processed with simple techniques. However, the decorative materials used in most rural classrooms often have quality and safety issues to varying degrees. Due to cost limitations and transportation difficulties, many modern new materials or construction techniques have not been applied in rural classroom spaces. The introduction of new spatial materials can not only improve the environmental friendliness and quality of rural classrooms but can even enable new teaching methods. This material limitation is exacerbated by two systemic factors: technical knowledge gaps among rural builders who lack awareness of modern safety standards, and fragmented supply chains that inflate costs of eco-friendly alternatives. Consequently, resolving this issue demands solutions that embed material safety training within local construction practices while optimizing regional logistics networks for affordable access to basic non-toxic materials.

2.2.3 Lack of regional characteristics

As vital carriers of rural culture, rural classrooms should reflect the regional characteristics of their locality. However, the vast majority merely undergo renovations of existing classrooms or are direct copies of models used in urban schools. Consequently, current rural classroom spaces fail to explore and integrate local regional characteristics and culture into their design, leading to uniformity and a lack of unique spatial language and features specific to their location.

Addressing these pressing issues in traditional rural classroom spaces, this paper proposes optimization strategies for constructing rural smart classrooms. Naturally, the construction of rural smart classrooms must be grounded in local needs and supported by national policies. Therefore, this paper also analyzes the feasibility of constructing rural smart classrooms as proposed.

3. Feasibility analysis of rural smart classroom space construction

3.1 Necessity of rural smart classroom space construction

The development and proliferation of technology have brought internet access, logistics, and various information and intelligent experiences to rural areas. Education, as a fundamental livelihood need, should also leverage these technological dividends to enter a stage of integration with smart technology. While smart classroom construction is often seen as essential hardware for urban education, its introduction into rural educational spaces can revitalize them with a new layer of vitality and character. On one hand, today's rural areas have long shed the stereotypes of "backwardness" and "dilapidation"; the internal driving force of rural development demands more stringent and diverse educational conditions. On the other hand, rural smart classrooms possess the dual characteristics of being both "rural" and "smart," which distinguishes them from urban smart classrooms.

3.2 National policies provide the foundation for rural smart classroom space construction

Rural education revitalization is an important component of the rural revitalization strategy. In recent years, numerous measures have been implemented for rural education revitalization, providing a

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solid foundation for constructing rural smart classroom spaces.

In July 2021, the Ministry of Education, the National Development and Reform Commission, and the Ministry of Finance issued the Opinions on Deepening the Improvement of Weak Links and Capacity Enhancement in Compulsory Education. These Opinions require that during the 14th Five-Year Plan period (2021-2025), continuous efforts should be made to improve basic school conditions, enhance the teaching level and quality of compulsory education, and prioritize strengthening weak links in rural compulsory education as a matter of overall importance. Effective measures should be taken to narrow the urban-rural and regional gaps, gradually achieve equalization of compulsory education resources, consolidate the basic achievements of balanced compulsory education, and accelerate high-quality balanced development and urban-rural integration[3].

In May 2022, the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council issued the Rural Construction Action Implementation Plan. This plan specifically addresses the shortcomings and weak areas in China's rural infrastructure and public service systems. The Digital Rural Construction and Development Project, listed as one of the key tasks, provides the software foundation for smart classroom construction. It enables rural classroom educational resources to leverage existing educational resource platforms, aggregating high-quality learning resources hierarchically and categorically for all teachers, including those in rural areas, to choose and use independently. This aims to continuously improve the informatization teaching capabilities and information literacy of rural teachers, expand pilot actions for using artificial intelligence to boost teacher team development, and build new models that utilize intelligent technology to support teacher development and optimize teacher management[4].

Building on this foundation, the analysis of necessity and national policies confirms both the feasibility and the significant importance of constructing rural smart classroom spaces. Therefore, from the perspective of design research, this paper proposes corresponding optimization strategies to address the existing problems in rural classroom spaces and promote the development of rural smart classroom spaces.

4. Optimization strategies for rural smart classroom space construction

The optimization strategies for rural smart classroom space construction explore design methods and approaches from multiple angles: composite spatial models, comprehensive functional facilities, vernacular building materials, and distinctive cultural attributes. These aim to optimize the problems inherent in traditional rural classroom environments, thereby narrowing the educational resource gap between urban and rural areas.

4.1 Composite spatial models

Given the current situation where the limited number of rural teachers necessitates teaching different subjects to multiple grades simultaneously within a single classroom space, educational researchers have proposed the "same-motion-same-quietness" composite teaching model. This involves one rural teacher instructing students from multiple grades within the same classroom space[5].

During the "same-quietness" phase, students from different grades independently complete their respective learning tasks, while the teacher instructs each grade separately based on their needs. During the "same-motion" phase, the teacher instructs all students simultaneously, with students undertaking learning tasks led by the teacher[6].

The "same-motion-same-quietness" composite teaching model is suitable for rural classrooms with scarce teaching resources (Figure 1). However, the traditional rural classroom spatial model is singular and static, unable to meet the demand for spatial mode transitions required by this composite teaching model. Therefore, corresponding to this composite teaching model, this paper categorizes spatial models into static and dynamic modes and proposes respective optimization strategies from the perspective of design research to embody spatial wisdom.

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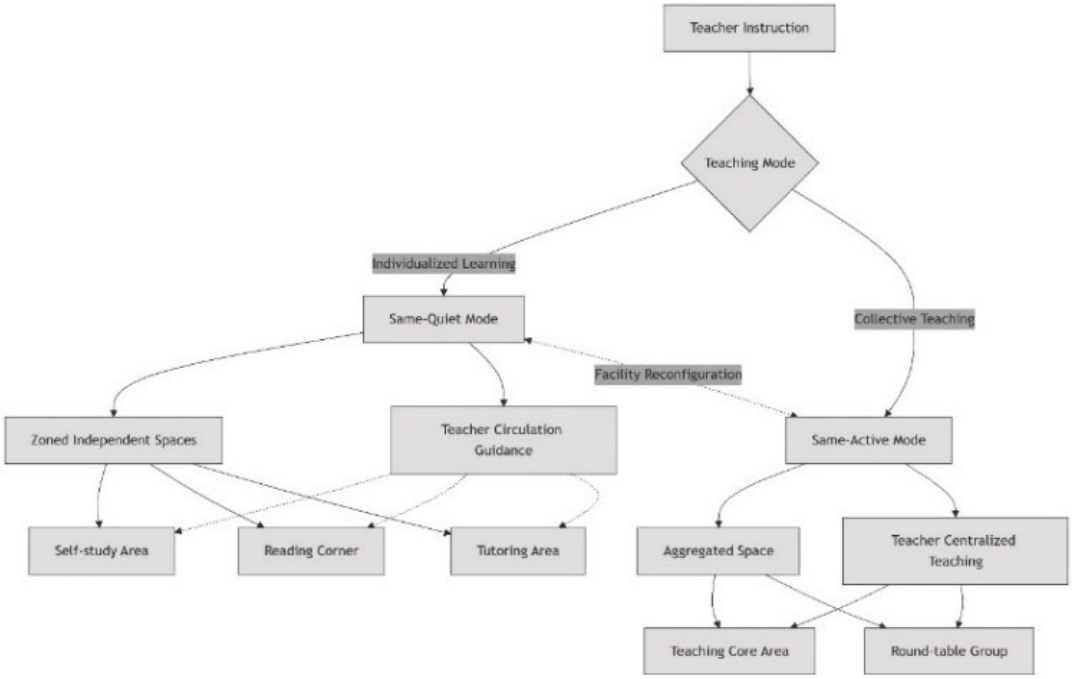

Figure 1: Spatial Transition Mechanism of Same-Active-Same-Quiet Teaching Model.

4.1.1 Static spatial mode

The "same-quietness" teaching mode emphasizes autonomous learning, where students from different grades and subjects freely participate and explore within the space. Students manage their own learning time, and learning content is not confined to the blackboard and textbooks. Instead, students are encouraged to utilize all facilities within the space to engage in self-directed learning, fostering more diverse interactions between students and the space. The teacher, no longer confined to the podium, instructs based on individual student needs, assisting them in utilizing spatial facilities to achieve their learning goals.

The static spatial mode corresponding to the "same-quietness" teaching model represents the informal teaching mode within the "same-motion-same-quietness" composite framework. It can be subdivided into self-study spaces, reading spaces, tutoring spaces, play spaces, etc. Under the "same-quietness" mode, students should be able to freely utilize various functional zones within the classroom space. This requires that different zones within the same space be relatively independent and non-interfering, presenting characteristics of behavioral interaction, functional composability, and flexible autonomy in the overall space. To achieve such flexibility, spatial subdivisions require hierarchical design principles---for instance, positioning acoustically isolated reading nooks behind bookshelf barriers, while maintaining visual permeability in tutoring zones for teacher oversight. Critically, transitional elements like sliding partitions must enable rapid reconfiguration between autonomous learning ("same-quietness") and collective instruction ("same-motion") modes, directly supporting the composite teaching model's dynamic needs.

4.1.2 Dynamic spatial mode

The "same-motion" teaching mode involves the teacher instructing all students simultaneously on the overlapping parts of the curriculum across different grades. It is primarily teacher-led instruction with student reception. Students from different grades collectively think about, discuss, and ultimately achieve understanding of the same knowledge point. This mode can partially alleviate the shortage of rural teachers, but it also imposes specific requirements on the classroom space.

The dynamic spatial mode corresponding to the "same-motion" teaching model mainly consists of a learning space and a teaching space. As it requires students from different grades to learn the same knowledge point together, the arrangement of student desks and chairs in the learning space differs from the traditional neat rows. Arrangements should be based on proximity in grade and age, similar to a round-table conference format, facilitating group discussion of teaching content among students from different grades under the "same-motion" mode, thereby maximizing the limited teacher resources.

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4.2 Vernacular building materials

The materials used in constructing rural classroom spaces are often simple, primitive, or, in many impoverished areas, limited to vernacular building materials processed with simple techniques. Vernacular spatial materials can reflect local characteristics and culture, creating a unique classroom space that fosters a stronger sense of belonging among students. At the same time, the appropriate introduction of new techniques and materials can enhance the stability of vernacular materials. Combining them with new materials can improve the environmental sustainability or quality of rural classroom spaces[7] (Figure 2).

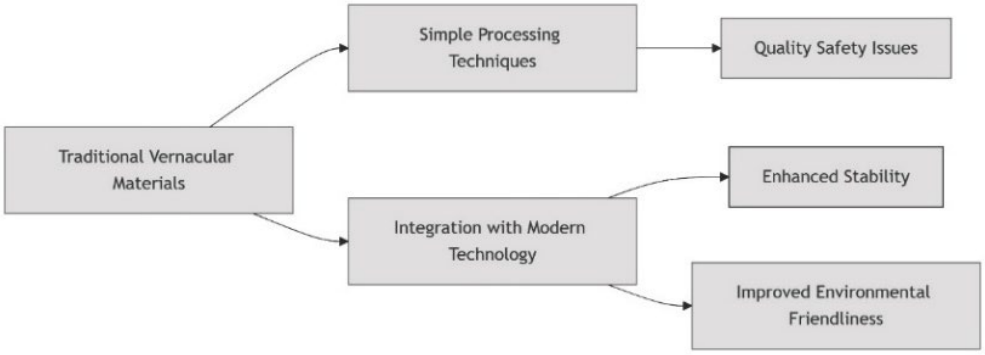

Figure 2: Innovation Path for Vernacular Material Application.3.

Exploring locally sourced materials with practical value and traditional construction techniques, and integrating them with new materials and techniques arising from modern industrial development, is a crucial approach to solving the problems of outdated materials and quality issues in traditional rural classrooms. Through the treatment of color, texture, and materiality of both old and new materials, the rural smart classroom space can convey an aesthetic of fusion between rural wisdom and modern intelligence. For instance, the METI School in Bangladesh (Figure 3) is a local rural primary school. The construction materials used for the school are all locally sourced earth and bamboo, and the construction workers were also local residents. During the construction process, the designers provided training on earth-bamboo construction techniques to these workers. By building the school, they simultaneously disseminated basic construction skills and knowledge to the local community, helping them utilize existing resources to create livable living environments as much as possible. Thus, the METI School exemplifies construction as pedagogy: by training workers in stabilized earth techniques, it empowered communities to apply these skills beyond the classroom. When students participate in bamboo preservation workshops using borax solutions, the material process itself becomes experiential science education---transforming the building site into a laboratory for sustainable practice.

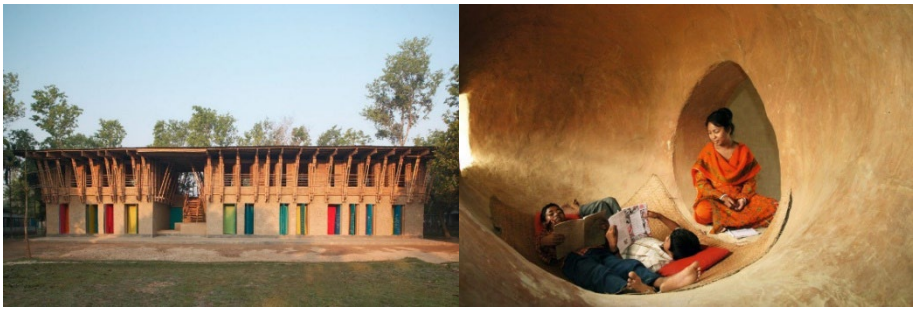

Figure 3: METI School

4.3 Distinctive cultural attributes

Regional culture is the soul of the countryside, and the rural classroom is a place for inheriting rural culture, bearing the responsibility of preserving and promoting it. Cultural differences mean that every region has its own unique language and philosophy for constructing rural classrooms[8].It is precisely these differences that create the diversity of a nation. Therefore, the construction of rural classroom spaces should be based on protecting the original natural landscape of the village, engaging in culturally contextualized building practices, and embodying the wisdom of rural culture in the spatial design. (Figure 4)

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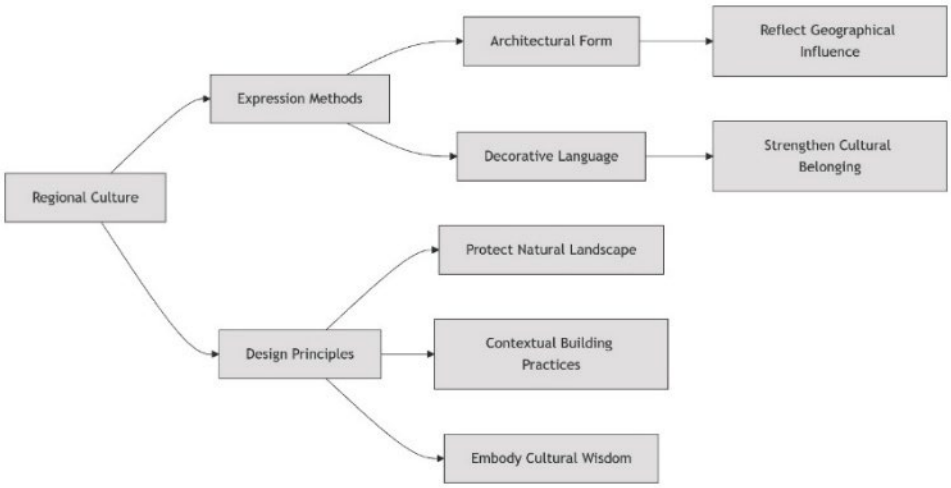

Figure 4: Cultural Expression Pathways.

The specific regional cultural attributes in a rural smart classroom can be primarily expressed through spatial form and decorative techniques. Under the influence of different geographical environments, rural populations develop unique cultural traditions and living habits. The impact of these unique lifestyles and cultural traditions is directly reflected in local architectural styles, giving rise to the distinctive spatial culture of the countryside. For instance, the Yuhu Complete Primary School in Lijiang, Yunnan (Figure 5), is situated in a small Naxi village at the foot of the Jade Dragon Snow Mountain. The designers distilled the essence of local vernacular architectural culture, maximizing the application and enhancement of indigenous cultural and architectural elements. This included preserving the pitched roof style and dividing the interior space using the traditional orthogonal bay division method. The completed campus seamlessly integrated into the village fabric, enabling children to both appreciate the beauty of their hometown and enjoy a high-quality learning environment. At Yuhu School, such cultural integration transcends aesthetics---the pitched roof's angle demonstrates physics principles, while abstracted patterns from Naxi textiles form math symmetry exercises. This transforms architectural elements into pedagogical tools, ensuring cultural heritage actively participates in daily learning rather than serving as passive decoration, thereby fulfilling the classroom's role as a dynamic cultural transmitter.

Figure 5: Yuhu Complete Primary School, Lijiang, Yunnan.

5. Conclusions

Based on the current development status of rural classrooms in China and grounded in the evolution of teaching models, exploring the specific development direction of rural classroom spaces is a crucial pathway to advance rural construction actions and further enhance the livability and suitability of rural areas for work. This paper identifies "spatial composability, vernacular materials, and distinctive cultural attributes"---summarized as the "Rural Smart Classroom Space"---as the main directions for future development. It is hoped that this research will provide valuable guidance for the renewal and optimization of rural classroom spaces. The "wisdom" of the rural smart classroom space is twofold: one aspect is the "software wisdom" brought by technological development; this paper explores the

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other aspect---"spatial wisdom"---which involves using limited space and resources to maximally meet the developmental needs of rural education in China. The construction of rural smart classroom spaces is not only an update and innovation in classroom space design but also aims to advocate for greater societal attention and assistance towards the development of rural children. These strategies collectively counteract rural education's triple marginalization---geographic isolation through adaptable spaces, resource scarcity via localized materials, and cultural erosion by embedded heritage. Future progress must track how such spatial innovations impact teacher retention and student-led cultural initiatives, measuring revitalization beyond physical infrastructure. It seeks to ensure that rural students can also access better educational resources and enjoy comfortable spaces for learning and activities, thereby narrowing the vast gap in educational resources between urban and rural areas.

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