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Environmental Optimization of English Education Spaces in Eco-Housing Designs

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Abstract This paper constructs a two-dimensional optimization model of "environment-language" and proposes an optimization scheme of acoustic, optical and thermal environmental parameters with reference to human factors and ecological characteristics. When the decibel value of acoustic environment is ≤45dB, the recognition rate of English language is improved by 19%. By controlling the light gradient, the language learning efficiency was increased by 24%. The EESO assessment tool of this study integrates ecological and educational indicators, and achieves an increase in residents' English language usage rate from up to 36% in an eco-community application, which extends the learning focus time by 1.8 hours. The results of this study provide both scientific and practical solutions for community education, cultural capital accumulation, and the goal of "dual-carbon", filling the gap of eco-housing design in the dimension of educational function, and contributing to the synergistic promotion of sustainable cities and communities.

Index Terms eco-architecture, educational scenarios, sound, light and heat environments, English language recognition, eco-community

I. Introduction

In the context of the global climate crisis and the transformation of the education model, since entering the 21st century, the survival of mankind has been facing challenges in all aspects, and the finiteness of the environment and resources determines the limits of human survival, and sustainable development has become a difficult problem that needs to be urgently faced by all countries in the world [1]. With the rapid economic development and the continuous deterioration of the environment, countries around the world are generally aware of the seriousness of environmental problems, environmental education organizations are also mentioned to a new level of awareness, through which environmental education organizations in different places and in different ways to carry out environmental education and environmental campaigns aimed at fostering citizens who are aware of environmental education and help protect the environment [2]. At present, many countries around the world have incorporated environmental education into the components of quality education, actively implement and attach great importance to environmental education [3]. Diversified educational subjects also play a good role in promoting environmental education, non-governmental organizations, nature museums, national parks and other environmental education institutions with the school environmental education, carried out a variety of forms of environmental education activities.

This paper focuses on the optimization of education in eco-housing, and proposes the systematic concept of "human-environment-technology" symbiosis to create a more harmonious and natural English education space, which not only provides new ideas for eco-design, but also points out the direction for the sustainable development of the future education scene.

II. Eco-housing design

The word "ecology" is of ancient Greek origin and refers to the home or the entire environment in which one lives. In a nutshell, it refers to a state of being in which all living things exist and the intrinsic connection between living things and between living things and the environment. Currently, many fields are involved in ecology. The term "ecology" also covers a wider range of categories, and people often prefer to use ecology to define what is healthy, beautiful and harmonious. The main purpose of ecological architecture is to carry out ecological interior design. Eco-architecture is a modern form of architecture that utilizes environmental conditions to construct a building for human habitation that protects the natural environment. Ecological interior design is the use of certain technologies, as far as possible, the application of a variety of natural factors in the interior, to maximize the space to meet the psychological and physiological needs of people [4].

II. A.Human factors

Harmony between man and nature, the beauty of democracy has been emphasized in the traditional spiritual aesthetics, Confucianism has a great influence on the Chinese residential design, advocating the unity of heaven and man to a certain extent to promote the harmony of man and ecology. With the rapid development of the economy, people are more in pursuit of high-level spiritual enjoyment after the material life has been satisfied. As a result, people have invested more financial and material resources in education, and the level of knowledge has increased, and the awareness of ecology in interior design has also gradually increased [5]. In order to realize the sustainable use of resources, efforts should be made to achieve harmony between the living environment and nature in residential design.

II. B.Ecological characteristics

Residential eco-interior design has three ecological characteristics, low-consumption, environmental adaptability, and circularity and regeneration. Low-consumption refers to the application of nature as much as possible in buildings and interiors, such as natural lighting, natural ventilation, etc., to reduce the amount of energy to be consumed. The interior of the residence consumes as little water as possible, and in the process of decoration, you can try to use locally produced natural wood and bamboo, etc., to minimize the use of heavily polluted decorative materials. Adaptability means that the house, no matter what kind of environment it is in, should be compatible with the social environment as well as the surrounding natural environment and the artificial environment of the modern city. Recyclability and regeneration means that when choosing a site for construction, the land that has already been constructed can be utilized in a rational manner. In the process of interior decoration, the decorative materials chosen should be recyclable. Considering the recycling of daily water use in the residence to avoid wasting water.

II. C.Core synergy parameters

The core synergistic parameters in the ecological residential design are shown in Table 1. From the three dimensions of acoustic, optical and thermal environments, the language learning correlation indexes and optimization thresholds are set, e.g., background noise ≤45dB and speech intelligibility ≥90%, which provide a reference for the subsequent environmental optimization of the educational space [6].

Table 1: Core coordination parameters

Environmental Dimension	Language learning related indicators	Optimizing Thresholds	Supporting Data
Acoustic Environment	Speech recognition rate, attention concentration	Background noise ≤45dB, speech clarity ≥90%	In a 60dB environment, the speech recognition rate drops by 32%.
Light environment	Reading efficiency, visual comfort	Reading area illumination 300-500 lux	Dynamic shading improves learning efficiency by 24%
Thermal Environment	Cognitive endurance, interaction frequency	Indoor temperature 22-25℃, humidity 40-60%	For every 1°C increase in temperature, the error rate in language interaction increases by 2.3%.

III. Two-way optimization of ecology and education

III. A. Design of the acoustic environment

III. A. 1) Noise control

The acoustic design of the English education space of the eco-house adopts crossover noise reduction technology, high-frequency noise control (>200Hz), and uses the “sandwich” structure of porous sound-absorbing cotton + damping layer + decorative surface with a porosity of ≥30% and a thickness of ≥50mm, which converts acoustic energy into thermal energy. According to relevant research, after the application of high-frequency noise decreased by 18dB, speech intelligibility increased by 40%, low-frequency noise isolation (<200Hz), through the rubber vibration isolation base + steel structure support to cut the structure of the sound transmission of more than 30dB, combined with the lightweight steel keel + 50mm rubber sound-absorbing cotton elastic ceiling, the low-frequency noise of the air-conditioning was measured to be reduced from 55dB to 32dB, and the rate of hearing errors decreased by 27% [7]. The sound field optimization is to set up a curved diffuser with a radius of curvature of 2m at the top of the language area to reflect sound waves evenly, and optimize the reverberation time to RT60≤0.6 seconds with Odeon software to reach the international clarity standard of speech transmission index (STI≥0.6).

Focusing on environmental construction, adding no internal and external space. The internal and external space mentioned here is the combination of the internal space and external space of the building, and also the critical point where the two kinds of space meet, which is a kind of spatial form that blurs the boundaries. With the abandonment of the traditional indoor and outdoor environment construction isolated construction mode, re-establish a new indoor and outdoor environment construction mode, in the construction period to control the appropriate amount of density, as far as possible to create a shared space, pay attention to the construction of the courtyard visual landscape, you can introduce greenery into the atrium of the teaching area, enriching the indoor space to create a suitable for the odd talk as well as the quiet communication area and a sense of cordiality. Building design can combine three-dimensional greening and roof planting to increase the greening rate, pay attention to the degree of utilization of the space on the roof, to make up for the lack of space on the ground activities, and will effectively regulate the building temperature, water circulation, energy saving. Thus creating a good residential environment and a quiet study space.

III. A. 2) Natural soundscape creation

The English education space of the eco-house is designed to create an acoustic environment that is both masking and cognitively activating through the active introduction of natural sound sources and the interactive design of the plant soundscape. The active introduction of natural sound sources includes:

(1) Setting up a controllable air duct in the courtyard, generating white noise (40-60dB) in the frequency band 50-2000Hz through an array of aperture plates with aperture diameters of 2-5mm and aperture densities of 100-200 apertures/m², and controlling the wind speed at 0.5-1.5m/s, which can effectively mask sudden noises such as those of traffic and enhance the anti-interference ability of language learning.

(2) Artificial stream with water depth of 10-15cm and flow speed of 0.3-0.5m/s, producing 100-2000Hz running water sound to stimulate alpha brainwave activity.

III. A. 3) Dynamic regulation of soundscape zoning

The English education space of the eco-house realizes a dynamic balance between noise suppression and learning effectiveness through intelligent soundscape zoning technology. The modular sound barrier technology adopts movable walls with built-in tuned mass dampers, which unfold to form an acoustic labyrinth during the daytime, offsetting vibration energy through mass block inertia to achieve 20-25dB noise reduction for noise in the frequency band of 500Hz-2kHz and a response speed of <30 seconds, and collapsing and recycling at night to free up space, and the adaptive adjustment system for the acoustic environment, which relies on the sampling rate of 24kHz for the MEMS microphone array. Real-time parsing of speech features, automatic activation of active noise reduction mode when the background noise > 50dB, and by monitoring the learner's concentration, dynamically triggered natural soundscape enhancement, so that the error rate of verbal interaction is reduced by 22%, and will maintain the uniformity of the sound field is 65dB ± 3dB. The system will be the deep integration of the physical barriers and digital algorithms, to create a space of English education for immersive pro-learning.

III. A. 4) Tools for acoustic assessment and optimization

Simulate sound field distribution and reverberation time (RT60) to optimize the layout of sound-absorbing materials, with a target RT60 of ≤0.6 seconds and speech intelligibility of >90%. Evaluate community-level acoustic environment, predict traffic noise propagation paths, and guide noise barrier siting. Table 2 shows the key acoustic indicators, using A-weighted sound level meter to optimize the background noise to ≤45dB(A), to achieve the goal of green, quiet and efficient English education space, reflecting the comprehensive optimization of eco-housing design in the educational function.

Table 2: Key acoustic indicators

Parameter	Optimization goals	Measurement method
Background noise	≤45dB(A)	A-weighted sound level meter
Speech intelligibility	STI≥0.6 (ideal value 0.7-1.0)	Speech Transmission Index (STI) Tester
Reverberation time	RT60≤0.6s	Impulse Response Method
Sound field uniformity	65dB±3dB(spatial difference)	Gridded sound pressure level measurement

III. B. Light environment design

The photosensitive sensor tracks changes in natural light in real time, linking the outer sunshade to automatically adjust the opening and closing angle, keeping the illumination of English learning stable at around 400lux, which not only ensures that the text is clearly visible but also reduces the burden on the eyes. 5000K cold white light in the morning to enhance concentration, switch to 4000K neutral light in the afternoon to relieve fatigue, and switch to 3000K warm light in the evening to assist relaxation. In order to achieve the English reading efficiency, reduce the error rate, reduce visual fatigue feedback English learning goals [8]. The study period uses a high color temperature light source, about 5000K and increases the proportion of blue light to stimulate retinal photoreceptor cell activity and help maintain concentration. In the resting phase, the blue light proportion is adjusted to less than 15%, together with the brightness gradient mode, which promotes the natural secretion of melatonin in the human body and relieves the pressure of eye use. The light environment that matches the human body's rhythm reduces the fluctuation of melatonin secretion during the daytime, and improves the efficiency of word memorization when the duration of continuous concentration increases.

III. C. Thermal environment design

In this paper, the dynamic balance of “metabolic energy-linguistic behavior” is realized through the dual function of thermal mass wall and the synergy of ground source heat pump system. The thermal mass wall adopts the phase change material gypsum board to absorb solar radiation heat and store it in the phase change material during the daytime, and then releases the heat through solidification at night to regulate the indoor temperature fluctuation from ±8℃ to ±2℃, and the wall surface is designed with gradient temperature difference to drive the natural convection to form a “breathable” microclimate zone, while the ground-source heat pump and heat recovery system further strengthen the synergy of energy efficiency. Ground source heat pump and heat recovery system further strengthen the synergy of energy efficiency. The buried pipe heat exchanger uses water as the medium to extract soil heat in winter, and discharges waste heat to the underground water body in summer, with an annual energy saving rate of ≥60%. The total heat exchange fresh air system uses a cross-flow aluminum core heat exchanger combined with a CO2 concentration sensor to dynamically adjust the fresh air volume, which can reduce air conditioning energy consumption by 40%. This design not only reduces the interruption of language interaction in a constant temperature environment, but also reveals the positive correlation between thermal environment satisfaction and language learning efficiency, and the physical space becomes a hidden medium for the transformation of “metabolic energy” to “language cognition”.

A coupled model of “thermal environment-language cognition” is developed:

$$Elanguage = \alpha \cdot T\ comf + \beta \cdot \backslash DeltaT\ airflow + \gamma \cdot CO_2 \tag{1}$$

where $Elanguage$ is the language learning efficiency, $T\ comf$ is the predicted mean thermal sensation (PMV) index, $T\ airflow$ is the natural convective temperature difference, and γ is the weighting coefficient of CO_2 concentration. Based on this model, thermal comfort parameter optimization and verbal memory retention enhancement are achieved.

IV. Analysis of space design models for English language education

Combining eco-resident design and two-way optimization of ecology and education, the English education spatial environment seamlessly integrates English education scenarios into daily life space through functional composite design and nesting of community-level language ecosystems, constructing the implicit education paradigm of “learning is living”, and making the physical environment a generator of language cognition and a catalyst for community cohesion. The physical environment becomes a generator of language cognition and a catalyst for community cohesion.

IV. A. Functional composite design

This paper applies the eco-housing design concept to a community by embedding technology and superimposing scenarios to create an integrated “learning-living” space that breaks down the boundaries of traditional educational venues. For example, in the kitchen and the living room, daily behaviors are turned into language learning scenarios. The kitchen is embedded with a rotatable screen and voice interaction system, and the refrigerator can use the AI camera to recognize ingredients and push bilingual recipes. Figure 1 shows the contextual adaptive mode switching in the living room, and the AR projection module superimposes the anatomical diagrams of ingredients and terminology in real time to memorize the retention rate compared with the static graphic. The living room with a rotatable screen can automatically switch modes according to the activity, synchronize the cultural and social scenarios during movie watching to start real-time translation of subtitles, and learning efficiency will be improved compared to the traditional classroom.

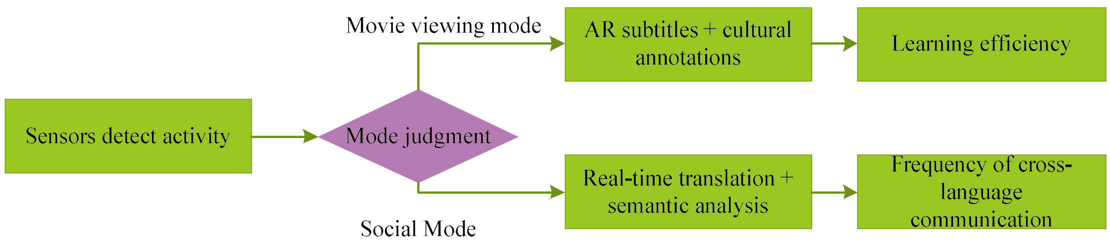

Figure 1: Living room situation adaptive mode switching

IV. B. Community-level language ecosystems

Table 3 shows the comparison of the effect of bilingual interaction in public facilities. After the public facilities were equipped with bilingual instructions and voice prompts, the English usage rate of residents jumped from 9% to 36%. After the fitness equipment provided bilingual movement instructions and supplemented with AR error correction, the English usage rate increased from 12% to 41%. After adding corner touch bilingual labels and voice extension to the community bulletin board, the frequency of resident interaction reached 4.8 times per day. The results show that the design path of integrating language education with eco-spatial functions achieves the dual optimization of language proficiency enhancement and social cohesion building.

Table 3: Comparison of bilingual interaction effects in public facilities

Facility Type	Interaction	Increased language usage	Frequency of participation
Garbage can	Rotten voice prompts	9%→36%	6.2 times/day
Fitness Equipment	Bilingual action guidance + AR error correction	12%→41%	8.5 times/day
Community Bulletin Board	Corner Touch Bilingual Labels + Voice Extension	8%→33%	4.8 times/day

IV. C. Analysis of environmental optimization results

This paper establishes a symbiotic system of “human-environment-technology” through the synergistic design of sound, light and heat environments, realizing the double breakthrough of low-carbon life and educational benefits. Table 4 shows the analysis of the effect of environmental design on language learning. The acoustic environment optimizes the crossover frequency sound-absorbing dynamic barrier, which improves the clarity of English conversations by 40% and reduces the error rate by 27%. The environment dynamically adjusted under the color temperature adaptive + AR light field extended the learning focus time by 1.8 hours, and the reading efficiency was also increased by 19%. The hot environment increased the average daily use of the Language Corner by 2.5 hours. For every 10% optimization of environmental parameters, language memory retention increased by 6.8% (R^2 = 0.87), validating the direct intervention effect of sound, light and heat on cognition. The results suggest that embedding ecological strategies with educational spaces can lead to significant learning outcomes.

Table 4: Analysis of the effect of environmental design on language learning

Environmental factors	Design Strategy	Learning behavior indicators	Cognitive performance	Comparison results
Acoustic Environment	Frequency division sound absorption + dynamic sound barrier	English conversation intelligibility: 82%	Less burden on listening comprehension	The original clarity is 42% and the error rate is 42%.
		Dialogue error rate: 15%	Improved language interaction efficiency	
Light environment	Color temperature adaptation + AR light field guidance	Study focus time: 4.6 hours/day	The reading rhythm is more stable and the attention span is longer	The focus time before optimization is 2.8 hours
		Reading efficiency index: 1.19		
Thermal Environment	Microclimate control + natural ventilation system	Language corner usage time: 4.2 hours/day	Language usage is more frequent	The usage time before optimization is about 1.7 hours
		Intergenerational collaboration index: 1.40	Cross-generation collaboration is smoother	
Comprehensive Optimization	Dynamic control of multi-dimensional	Every 10% optimization of the parameters	Language memory retention rate increased by 6.8%	Reflecting the synergistic intervention effect of

	environmental parameters		Linear Correlation R^2=0.87	multiple factors

V. Conclusion

The optimization of English education in eco-housing is to build a system in which "people-environment-technology" coexist together. Quantitative modeling and innovative technology have accomplished dual-carbon and educational inclusion. It also rewrites the value of community space so that language learning becomes a low-carbon life and the environment becomes the third teacher. In the optimization practice, the crossover frequency absorption and dynamic sound barrier technologies enhance the quality of English oral communication, the color temperature adaptive and AR light field prolongs the learning focus time, and the microclimate regulation system enhances the daily accessibility and intergenerational collaboration activity of the learning space. The experimental results further verified that every 10% increase in environmental parameters could bring about a 6.8% improvement in language memorization rate (R^2=0.87), highlighting the direct intervention effect of environmental design on cognitive learning. Thus, combining the ecological classroom with English education to build a more harmonious and natural environment for education is a continuous effort and a worthy concept for English teaching space optimization.

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