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From Knowledge Transmission to Scientific Literacy Cultivation: Innovative Design and Dissemination Strategies of the Course Biological Science Popularization Education

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Abstract: *Science popularization is an important lever to enhance the scientific literacy of the whole nation, and universities play a key supporting role in the science popularization and education system. The systematic construction of biological science popularization courses can cultivate composite talents with solid biological professional skills and practical abilities in science popularization. This study is based on the theoretical achievements and practical experience in the field of biological science popularization, and constructs a characteristic curriculum system of "one body, two wings, and three dimensions". This system takes experiential learning as its core, with scientific thinking shaping and science popularization ability cultivation as its dual support. It builds a four tiered progressive teaching module of cognition, experience, creation, and dissemination, and improves the implementation mechanism through course product development, library school collaboration, and professional teacher training. It promotes the curriculum to break away from the traditional indoctrination mode and achieve a deep transformation from single knowledge teaching to comprehensive science popularization education and empowerment.*

Keywords: *Biological Science Popularization Education; Innovative Curriculum Design; Experiential Learning; Dissemination Strategies*

1. Introduction

Life science popularization teaching combines the dual attributes of on campus scientific education and social science popularization promotion, relying on easy to understand knowledge interpretation, scenario based classroom creation, and hands-on practical activities to simultaneously complete the two core tasks of scientific content transmission and rational exploration literacy shaping. Compared to standardized biology classrooms, the core advantage of this teaching model lies in bidirectional collaborative development: on the one hand, it strengthens students' basic subject cognition, and on the other hand, it exercises their comprehensive literacy in science popularization and practical output.

The overall architecture of the course is mainly supported by experiential learning related theories. The four stage learning cycle framework constructed by Kolb includes four stages: personal perception and experience, review and observation, induction and refinement of theories, and practical verification. It clearly elucidates the intrinsic path of human cognition from intuitive perception to logical thinking, and from personal practice to system theory. Experiential oriented teaching transforms obscure professional theories into intuitive, participatory, and personally felt practical projects, allowing knowledge to no longer rely on one-way passive teaching, but instead rely on learners to independently organize and internalize, effectively bridging the gap between the depth of popular science content and the existing cognitive level of the audience.

2. Theoretical Foundation and Practical Review of Life Science Popularization Education

2.1 Core Definition and Theoretical Basis

At present, there are various implementation paths for life science popularization and education in

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China. The 2W1H analysis framework designed by Hu Xinyi's team clarifies the three core elements of science popularization work: goals, materials, and implementation methods, and provides feasible ideas for integrating science popularization into university plant subject classrooms; The research team has built a four-dimensional implementation system for HRCT, breaking down the complete process of science popularization into four major sections: hands-on practice, speculative review, conceptual induction, and expanded preaching, creating a standardized implementation paradigm that can be widely promoted.[1]

Based on the division of landing scenarios, life science popularization education is carried out in multiple spaces through coordinated development: theme sharing sessions, on campus characteristic courses, extracurricular exploration experiments, science museum research and other forms of activities are developed synchronously. At the practical level of universities, Fudan University has built an online VR digital exhibition hall based on its collection of specimen materials[2]; East China Normal University has launched a "Life Exploration" characteristic classroom, linking affiliated primary and secondary schools in various regions, and building a coherent scientific cultivation system that runs from basic education to higher education.

2.2 Multidimensional examination of practical models

Currently, a mature and diverse practical system for biological science popularization education has been formed in China. The "2W1H" analytical framework proposed by Hu Xinyi clarifies the core elements of science popularization education and provides theoretical support for the transformation of science popularization in university biology courses, focusing on deep knowledge mining, integration of scientific research and teaching[3], and diversified science popularization output paths. The "HRCT" four-dimensional model constructed by Mudan is based on experiential learning theory, promoting the standardization of science popularization teaching processes and forming a set of operable and promotable integrated science popularization education paradigms both inside and outside the classroom.

At the practical level, biological science popularization education is showing a trend of integrated development in multiple scenarios, with various forms of science popularization teaching both inside and outside the school promoting and complementing each other. Existing research has focused on interesting thematic teaching, organic integration of science popularization and ideological education, and interdisciplinary project practice[4], continuously optimizing teaching models and effectively promoting the improvement of students' scientific literacy and comprehensive abilities. At the same time, universities continue to deepen their science popularization education mechanisms, gradually building a comprehensive and hierarchical life science popularization education system through measures such as digital science popularization resource development and collaborative education between different stages, providing solid support for the systematic implementation of science popularization education.

2.3 Existing problems and entry points for curriculum innovation

Although biological science popularization education has achieved certain results, it still faces multiple structural challenges. One issue is that the curriculum positioning is vague, and popular science activities often become mere formalities, failing to integrate into the formal teaching system and lacking systematic goals and evaluation criteria. The second issue is insufficient resource conversion, with poor connection between high-quality resources such as university research platforms and specimen facilities and popular science teaching[5], resulting in structural contradictions of "sufficient supply but inefficient utilization, strong demand but limited participation". The third issue is the fragmented connection between academic stages, with science popularization education in primary, secondary, and tertiary schools operating independently and lacking vertical integration design[6],. Fourthly, there is a shortage of talent reserves, and the ability to create popular science has not been included in the training of normal students, resulting in a significant shortage of professional teachers.

In summary, the paradigm shift of biological science popularization education from "activity-based" to "curriculum based" and from "sporadic" to "normalized" has not yet been achieved. This delay in transformation is the real reason for constructing a systematic curriculum innovation framework in this article.

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3. The "Main Body, Two Wings,Three Dimensions" Curriculum Innovation Framework

3.1 Design Philosophy and Targeted Learning Outcomes

The curriculum adheres to the core concept of "experience as the engine, creation as the driving force, and dissemination as the goal". Compared with the traditional science popularization teaching mode, it presents three outstanding advantages: firstly, upgrading from scattered and occasional science popularization activities to a systematic and normalized curriculum system, making science popularization education truly embedded in the talent training program of universities; Secondly, shifting from single knowledge imparting to the generation of core competencies, focusing on the coordinated development of scientific thinking and practical skills in science popularization; Thirdly, shifting from one-way knowledge dissemination to two-way educational empowerment, students deepen their own cognition while outputting popular science achievements, achieving mutual growth between teaching and learning.

The course objectives are set at three progressive levels: at the cognitive level, students are required to systematically master the core concept system of biology and form a solid foundation of subject knowledge; At the capability level, the focus is on cultivating three core abilities: extracting and planning popular science themes, designing and organizing popular science programs, and creating and expressing diverse popular science works; At the level of literacy, efforts should be made to shape a comprehensive literacy that organically integrates scientific spirit, social responsibility, and communication awareness, so that students can grow into a reserve force for science popularization education that combines academic background and public communication literacy through the two-way interaction of knowledge internalization and ability externalization. The three-dimensional goals progress layer by layer and support each other, jointly pointing to the integrated talent cultivation orientation of "knowledge ability element".

3.2 Structural design of "One Main Body, Two Wings"

The "one main body, two wings" is the core architecture of the "Biology Science Popularization Education" curriculum system. Among them, "one main body" establishes experiential learning as the core position, and follows the "HRCT" path to transform Kolb's four stages into practical processes: the handmade experience stage establishes intuitive cognition through practical activities such as leaf vein painting and microscopic observation; In the stage of scientific reflection, a progressive problem chain is used to guide exploration and upgrade; Integrating scattered experiences into a systematic knowledge system during the conceptual construction phase; The transfer and dissemination stage completes the closed loop of "knowledge input ability output" and realizes the socialization extension of learning outcomes.

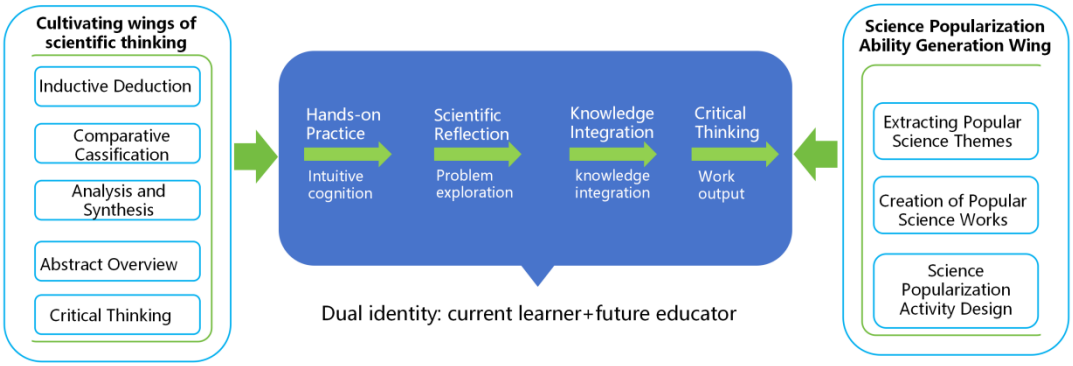

Figure 1 The structural framework design diagram of the "one main body, two wings" model

The "two wings" respectively support the cultivation of scientific thinking and the generation of science popularization ability, and work together to support the "integrated" operation. The cultivation of scientific thinking covers five dimensions: induction and deduction, comparative classification, and critical thinking, which run through all aspects of cognition, experience, and creation, cultivating students' rational judgment; The generation of science popularization ability focuses on three core skills: theme extraction, work creation, and activity design, which are in line with the dual identity of teacher

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trainees and provide them with professional qualities. The deep integration of the three forms a virtuous cycle of "experience driven thinking, thinking support ability, and ability feedback experience", promoting the coordinated development of students' knowledge acquisition and dissemination abilities. The structural framework design diagram of the "one main body, two wings" model is shown in Figure 1.

3.3 The Four-Tier Progressive Teaching Module: Cognition→Experience→Creation→Communication

The course is designed in a four step progression: the cognitive module focuses on core concepts and social connections[6]; The experience module concretizes abstract knowledge through "hands-on+" approach; The creation module achieves the popularization of knowledge through popular science videos, picture books, teaching aids, and other works; The dissemination module connects the learning loop and relies on audience feedback to achieve strategy iteration.

The content of this course follows a fourth-order progressive logic of "cognition experience creation dissemination", constructing a spiral upward path from knowledge input to value output, enabling students to complete the role transformation from subject comprehension to science popularization practitioners in a step-by-step and in-depth learning process.

The first stage is the cognitive module, which focuses on the core concepts of biology and their deep connections with social issues. This module breaks the traditional linear teaching mode of textbooks and adopts a theme based and problem oriented teaching strategy to guide students to explore the inherent connections between biological knowledge and contemporary themes such as ecological civilization construction, rural revitalization strategy, and public health events. It helps students establish a meaningful bridge between subject knowledge and social reality, and inspires learning motivation and social responsibility.

The second stage is the experience module, with "handmade+" practice as the core, designing immersive activities such as leaf vein painting production, blue sun drying process experience, and microscopic structure observation. Through embodied hands-on operations, abstract biological principles are transformed into tangible experiences that are perceptible and touchable, effectively lowering cognitive barriers, stimulating students' interest in exploration and scientific curiosity, and laying a sensory foundation for subsequent creative output.

The third stage is the creation module, which is also the core output link of the course. Students need to comprehensively apply the knowledge and experience accumulated in the early stage to carry out creative tasks such as shooting science popularization videos, compiling science popularization picture books, and designing science popularization teaching aids, completing the transformation from professional terminology to popular language, and the leap from disciplinary logic to communication logic. This module focuses on enhancing students' abilities in knowledge integration, innovative expression, and project planning.

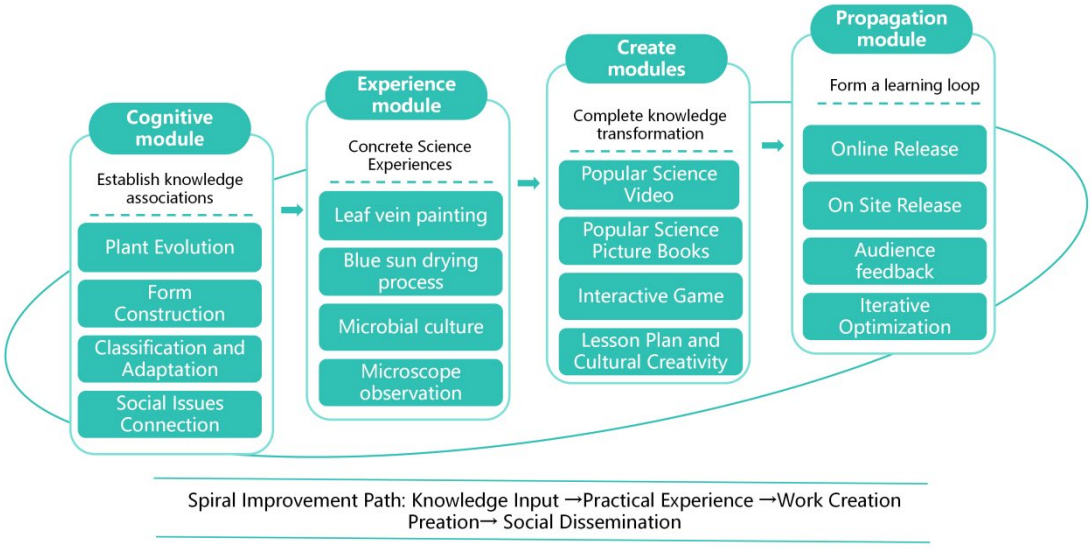

Figure 2 The four-Tier progressive teaching module diagram

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The fourth stage is the dissemination module, aimed at breaking through the complete closed loop of "learning doing transmitting". It selects excellent popular science works, disseminates them to the public through various channels such as campus exhibitions, online platforms, and community outreach events, and relies on real data—including audience views, interactive comments, and feedback—to guide students in evaluating communication effectiveness, reflecting on creative strategies, and achieving continuous iteration and optimization of their science communication and presentation skills. The fourth-order modules are interconnected and progressively constructed, together forming a complete educational chain from knowledge acquisition to social influence. The four-Tier progressive teaching module diagram is shown in Figure 2.

3.4 Diversified Multi-Dimensional Assessment System Design

This course breaks through the single evaluation limitations of traditional paper and pencil tests, focusing on building a diversified evaluation system that emphasizes both process and outcome, and combines internal evaluation with external feedback. It strives to comprehensively and objectively measure students' comprehensive performance in knowledge mastery, ability development, and literacy improvement.

In terms of evaluation subjects, the course adopts a comprehensive evaluation model of "teacher evaluation+inter group mutual evaluation+public evaluation" through tripartite collaboration. Teacher evaluation focuses on examining the scientific and rigorous nature of popular science works, ensuring that the content is accurate and error free; Inter group peer evaluation guides students to critically examine peer outcomes, promoting mutual learning and reflection; The public rating system introduces intuitive feedback from the general public, enhancing the openness and authenticity of the evaluation. The weights of the three factors should be allocated appropriately to ensure complementarity and prevent bias toward any individual subject.

In terms of evaluation dimensions, the curriculum is systematically assessed from four core levels: scientificity, innovation, interactivity, and communication effectiveness. Scientificity focuses on the accuracy and logical rigor of knowledge expression, innovation measures the uniqueness of topic selection perspectives and presentation methods, interactivity examines the attractiveness and participation of popular science works to audiences, and communication effectiveness focuses on the efficiency and scope of information transmission. Multi-dimensional evaluation design helps to comprehensively capture students' overall ability performance.

In terms of evaluation methods, the course introduces a three-stage descriptive evaluation of "highlights improvement points insights" to replace the single score oriented approach. After completing popular science works, students need to extract highlights, identify shortcomings, and summarize their insights around their own achievements, in order to promote deep reflection and metacognitive development. At the same time, the course will incorporate the online dissemination data of popular science works, including reading volume, forwarding volume, interactive comments, etc., into external evaluation criteria to accurately measure the social effectiveness and actual influence of the course, and achieve effective extension of teaching effectiveness from within the classroom to outside society.

4. Implementation and promotion strategies for the implementation of 4 biological science popularization education courses

4.1 Curriculum Standardization Product Construction

To facilitate the large-scale promotion of courses, a standardized teaching curriculum package can be created, integrating supporting teaching aids, teaching courseware, teacher manuals, and quantitative evaluation scales. The course adopts a combination architecture of "core module+flexible module". The core module ensures the implementation of the curriculum's educational philosophy and teaching objectives, while the flexible module adapts to the educational conditions and learning situations of different regions and schools, balancing teaching standardization and flexible adaptability, achieving an organic integration of standardized promotion and localized adjustment.

4.2 Collaborative Education Construction between Libraries and Schools

Based on the research driven cooperation model between the library and the university, we promote

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researchers to transform their professional research results into popular science content, collaborate with education experts to complete teaching adaptation and transformation, and build a complete educational chain of "scientific research mining curriculum transformation classroom implementation". This approach simultaneously integrates physical venues, online platforms, and virtual simulation experiment resources, builds an integrated resource sharing system, overcomes time and space limitations, and achieves comprehensive coverage and efficient reuse of high-quality popular science resources.

4.3 Building a hierarchical teaching staff team

Build a four tiered faculty team that links universities and primary and secondary schools, clarify the division of labor among all parties: university experts are responsible for curriculum development and content optimization, teacher trainees participate in teaching practice as teaching assistants, primary and secondary school teachers undertake regular teaching work, and venue personnel provide science popularization support. Multi party collaboration and cooperation form a complete closed loop of curriculum design and teaching implementation, achieving two-way empowerment of teacher training and long-term promotion of courses.

5. Conclusion

The course of "Biological Science Popularization Education" promotes the triple transformation of university biology teaching.In terms of educational orientation, it shifts from cultivating traditional subject-specific talents to systematically fostering interdisciplinary professionals capable of science popularization. In pedagogical approach, it moves beyond one-way knowledge transmission toward inquiry-based teaching that integrates experiential learning with project-driven creative practice. In terms of educational mission, it extends from serving on-campus students to empowering broader public engagement in scientific communication.

The "One Core, Two Pillars, Three Dimensions" curriculum framework proposed in this study requires further validation through extensive empirical research. Future work should focus on conducting large-sample teaching experiments across multiple regions and educational levels, developing quantitative assessment tools that cover cognitive, attitudinal, and behavioral dimensions of science literacy, and exploring the long-term mechanisms by which biology classrooms can facilitate the public's transition from passive knowledge recipients to active disseminators of scientific culture. Such efforts aim to provide more robust theoretical foundations and actionable pathways for the implementation of science popularization education in higher education institutions.

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