Research on the Application of STSE Education in High School Biology Teaching

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Abstract: Science, Technology, Society, and Environment (STSE) education is an interdisciplinary framework that emphasizes the dynamic interconnections among scientific inquiry, technological advancement, social progress, and environmental stewardship. This teaching model focuses on deconstructing the actual effectiveness of technological innovation in industrial upgrading, ecological restoration, and the evolution of civilization. By building a dynamic analysis model of science, technology, society, and environment, it forms a teaching form with systematic integration characteristics. At the level of biology curriculum implementation, integrating the STSE framework addresses the demand for cultivating core competencies, a key goal of basic education reform. Furthermore, by reconstructing knowledge within authentic contexts, it promotes the development of learners' deep cognitive schemas. This approach effectively enhances their practical abilities in scientific argumentation and decision-making, thereby achieving a dual goal: the acquisition of knowledge and the development of social responsibility. This paper analyzes and studies the significance, penetration status, and application of STSE education in high school biology teaching and provides corresponding summaries and prospects.

Keywords: STSE Education; High School Biology Teaching; Core Competencies; Teaching Integration; Textbook Analysis

1. Introduction

Contemporary technological innovation, while promoting leaps in social productivity, simultaneously gives rise to complex challenges such as energy structure transformation, resource regeneration bottlenecks, ethical controversies over new materials, and the breaching of ecological carrying capacity thresholds. These concomitant crises have surpassed the scope of traditional technological governance and pose systemic risks to ecosystem sustainability. From an interdisciplinary perspective, the solutions to these challenges are deeply coupled with breakthrough progress in frontier areas of life sciences such as gene editing, bioremediation, and synthetic biology. The deep correlation between life sciences and social development determines its special value in the educational field. As a fundamental discipline spanning practical fields like healthcare, agricultural production, and ecological governance, biology education urgently needs to construct an STSE-oriented cognitive framework. By revealing the interaction mechanism between life laws and socio-technological applications, it can not only enhance the realistic explanatory power of disciplinary knowledge but also cultivate learners' civic scientific literacy in dimensions such as ethical speculation and technology assessment, achieving the effective integration of knowledge acquisition and social responsibility. With the implementation of the new curriculum reform, the "Biology Curriculum Standards for Ordinary High Schools (Experimental)" promulgated by the Ministry of Education in March 2003 explicitly proposed content related to permeating the STSE education concept in teaching, allowing students to correctly understand the relationship between science, technology, and society during the learning process [1]. The new curriculum standards, proposing the concept of cultivating students' "life concepts, scientific thinking, scientific inquiry, and social responsibility," coincides with STSE education [2]. STSE education can make high school biology classes more vivid and practical. Previous biology teaching might have been conducted by rote from textbooks, whereas now it more often involves leading students to discuss real-world

issues, such as explaining virus knowledge in conjunction with frequent flu outbreaks or discussing ecological protection using garbage classification. Such classrooms not only have content closer to life but also richer teaching forms. Then, by adding activities like experiments, social surveys, and debates, students can truly apply knowledge, which helps make the originally relatively closed teaching model more open and effectively improves both the content and form of high school biology teaching.

2. The Significance of STSE Education in Biology Teaching

2.1 Enriching Curriculum Content

STSE is an acronym formed from the initial letters of Science, Technology, Society, and Environment [3]. Evolving from the STS education paradigm, the theoretical framework of STSE extends its research scope into the ecological dimension. It organically integrates the core elements and cognitive frameworks of socioscientific issues curricula, forming a multidimensional educational system. With the deepening advancement of competency-oriented curriculum reform, this theoretical system is not only established as a pillar for cultivating key competencies in biology and chemistry-related subjects but also serves as a strategic support system for the modernization of science education. It is dedicated to helping learners construct a cross-dimensional cognitive framework encompassing the four spheres of science, technology, society, and environment, enabling them to deeply understand the dynamic mechanisms inherent in their interactions. Through interdisciplinary integration strategies, the STSE curriculum system incorporates socio-economic development, ecological environment governance, discussions on scientific ethics, and public health issues into the teaching framework. It employs a composite knowledge construction model to guide learners in mastering core disciplinary concepts while simultaneously developing a multidimensional cognitive network for understanding complex social issues through value judgments and ethical deliberation.

2.2 Shifting Learning Paradigms

With the continuous development of society, China's education is gradually aligning with international standards, especially in teaching philosophies and models, which are undergoing significant changes. To enable students to meet the needs of contemporary society, educational reform is an inevitable process. By implementing the permeation of STSE education in biology teaching, traditional teaching thinking is practically transformed [4]. First, it no longer solely pursues test scores and enrollment rates but focuses on whether students understand and can flexibly apply the knowledge they have learned; second, it no longer focuses solely on lecturing but strengthens the concept of student-centeredness, cultivates students' autonomous learning awareness, and, from the students' perspective, enhances their exploration, research, construction, and other learning abilities. STSE education emphasizes that students can understand the knowledge they learn and can apply the biological knowledge acquired in school to practice, matching social life. The STSE education system is goal-oriented towards enhancing human well-being, promoting the sustainable development of ecological civilization through knowledge application, and elevating knowledge acquisition to the dimension of value creation. Its teaching design core lies in guiding the learning subject to establish a scientific cognitive system through project-based practices, specifically adopting hybrid strategies such as thematic debates, immersive scenario construction, and collaborative learning games, focusing on cultivating learners' dialectical analysis ability and evidence-driven decision-making literacy in real-world problem exploration, ultimately constructing an ability framework that unifies scientific rationality and social responsibility. Compared to traditional teaching methods, STSE emphasizes the procedural experience of knowledge construction. By setting inquiry tasks in real scenarios, it guides students to gradually establish a scientific spirit and values through practical exploration, deeply understand and master the scientific inquiry methods to be applied in biology [2].

2.3 Enhancing Scientific Literacy

"Scientific Literacy" is generally summarized as consisting of three components: understanding scientific knowledge; understanding the process and methods of scientific research; and understanding the impact of science and

technology on society and individuals [5]. It specifically refers to the ability to use scientific methods, master scientific thinking and scientific ideas. From the perspective of educational taxonomy, these contents are essentially a metacognitive support system for cultivating empirical research ability, complex problem modeling ability, and interdisciplinary integration ability. They are also key elements necessary for students to become lifelong learners, maintaining thinking and inquiry awareness about the world around them. STSE education believes that "scientific inquiry is the core of science and science learning." Teaching design based on constructivist learning views focuses on strengthening learners' embodied cognitive process of transferring and applying research methods. By creating inquiry-driven teaching scenarios, learners are guided through the complete cognitive cycle of hypothesis generation, scheme design, and empirical testing, achieving the bidirectional construction of operational skill acquisition and cognitive monitoring systems in this process. This teaching method, by simulating the cognitive approach of scientific researchers, enables educatees to gradually form a dynamic feedback mechanism between scientific practice and higher-order thinking, while learning and mastering scientific methods, exercising scientific thinking, developing scientific qualities, and cultivating scientific attitudes through inquiry. Furthermore, to fully organically integrate STSE education with biology teaching in comprehensive practical activities, it also requires teachers to establish new educational concepts, continuously learn new educational theories, strengthen their own literacy, broaden their knowledge, be good at reflection and summarization, and be able to organize teaching activities orderly, guide students to independent inquiry, encourage them during the inquiry process, strengthen their self-confidence, maintain their motivation for self-inquiry, and, under the STSE framework, through teaching activities that construct cross-domain knowledge connections, guide learners to deepen their cognition of the social ecosystem in real situations, thereby strengthening their environmental awareness and civic responsibility, and ultimately cultivating their scientifically ethical concept of sustainable development. Overall, from the perspective of the goals of science education, STSE education has shifted from past one-sided personal development to cultivating and enhancing the scientific literacy of the entire population.

3. Application and Analysis of STSE Education in High School Biology Teaching

3.1 The STSE Education Concept in High School Biology Textbooks

Taking the People's Education Edition high school biology textbook as an example, both old and new editions have special sections named "Science·Technology·Society," serving as the core section concentratedly reflecting the STSE concept in the textbook. This section not only dominates in content length but also becomes an important carrier for teachers to implement interdisciplinary education. Its compilation structure intuitively presents the organic integration of science and social issues, building a practical bridge for classroom teaching from knowledge learning to the transfer of real-world issues [6], reflecting the textbook compilers' emphasis on STSE education and the implementation of the general direction stipulated in the "Biology Curriculum Standards for Ordinary High Schools (2020 Edition)" for cultivating students' core biological literacy. Furthermore, after a overall analysis of the new People's Education Edition high school biology textbook, a total of 21 special sections were counted. After removing the review and summary sections "After-class Exercises", "Review and Improvement", and "Chapter Summary", the remaining sections can be divided into three categories according to three aspects: thinking and discussion, inquiry practice, and knowledge expansion.

The thinking and discussion category includes Problem Discussion, Focus of This Section, Think·Discuss, Sidebar Thinking Questions, Critical Thinking, Imagination Space, and Thinking Training. These mainly involve cultivating students' scientific inquiry thinking, interspersed with a small amount of STSE education concepts, aiming to provoke student thinking, allowing students to independently connect biology with the four sectors related to STSE education, and gradually expand students' exploration and construction thinking abilities in subsequent learning.

The inquiry practice category includes Careers Related to Biology, Inquire·Practice,

Science·Technology·Society, Connections to Society, Extracurricular Production, and Scientific Method. The setting of this category is mainly to cultivate students' practical inquiry ability. According to the titles of each section, it can be seen that the content explained is directly linked to the four sectors included in STSE education. The STSE education concepts involved here account for the vast majority of the entire textbook, also emphasizing the textbook's implementation of core biological literacy. In addition to the "Science·Technology·Society" section which can more intuitively reflect STSE education, the STSE education concepts involved in the "Careers Related to Biology" section are also emphatically analyzed. Here, the content of "Breeding Worker" mentioned in the "Careers Related to Biology" section in Chapter 1, The Discovery of Genetic Factors, of the People's Education Edition High School Biology Compulsory 2 "Genetics and Evolution" is selected for illustration. The "Science" connotation involved includes theoretical foundations such as genetic recombination (gene separation, free combination, DNA recombination), gene mutation, chromosomal variation, nuclear transplantation, and the theory that suitable concentrations of auxin can promote fruit development; the "Technology" knowledge contained includes multiple related scientific technologies such as transgenic technology, hybrid breeding, artificial mutagenesis breeding, haploid breeding, polyploid breeding, and genetic engineering (directional breeding of new species, using "cell engineering" for breeding, using plant hormones to cultivate specific traits); the "Society" concept emphasizes: applying crop breeding in agricultural production can not only improve food production levels but also ensure the effective implementation of the "food security" strategy, and through genetic improvement of crops, high-yield, stable-yield, high-quality, and efficient fine varieties of crops can be selected and bred, improving yield and benefit per unit area; the "Environment" aspect involves that breeding workers can be close to nature during the breeding process and can continuously promote the development of breeding technology, finding breeding technologies that can not only cultivate efficient and high-quality crops but also reduce environmental pollution. It can be seen that the STSE education concept reflected in the above content is relatively complete and comprehensive. The setting of such knowledge sections allows students to understand biological theoretical knowledge while also infiltrating its application in life. Students can understand the learned content more deeply based on examples close to life, and also understand the significance of biology for humans, nature, life, and society, appreciate the importance and necessity of biology more, and strengthen their attention to biology. Plus, this section has a certain interest and exploratory nature, thereby stimulating students' interest in biology learning.

In addition, the knowledge expansion category includes Advances in Biotechnology, Interdisciplinary, Knowledge Links, Related Information, and History of Biological Science sections. The STSE education concepts contained therein are also relatively rich. For example, the Advances in Biotechnology section involves the application and development of biology in various aspects of human history, not limited to the four major sectors involved in the STSE education concept, but this will not be elaborated further here.

3.2 The STSE Education Concept in High School Biology Teaching Activities

3.2.1 Implementing STSE Education in Teaching Activities to Promote the Cultivation of Students' Core Competencies

Biological STSE education promotes the cultivation of students' core competencies [7]. In terms of life concepts: Applying the STSE concept to guide student learning can better enable students to understand and summarize observed life phenomena and their interrelationships; in terms of scientific thinking: Correct the attitude towards knowledge, make students more rigorous and careful in scientific inquiry, able to use scientific thinking to solve practical problems, and develop students' inductive and deductive abilities, verification and hypothesis abilities, dialectical thinking, and creative thinking, etc.; in terms of inquiry practice: Enable educational activities to effectively cultivate students' inquiry ability, allow students to master basic knowledge and skills related to experiments, value the connection between biology and other disciplines, be able to comprehensively use relevant knowledge and skills to analyze and solve some problems faced by humans in social

life, and promote their active construction of knowledge while developing their abilities; in terms of social responsibility: STSE education can help students distinguish between superstition and pseudoscience, promote knowledge related to healthy living, caring for life, and protecting the environment, and also allow students to understand and master methods to solve the sustainable development of humans, nature, and society, cultivate students' awareness of sustainable development and their ability to participate in practice, and enhance their emotions of loving their hometown and country [8].

3.2.2 Flexibly Permeating STSE Education through Multiple Channels

There are three important stages in the classroom where STSE educational ideas can be permeated, such as the beginning stage--introducing new lessons, the development stage--presenting new knowledge, the ending stage--concluding the lesson. Flexibly using these links can achieve the effect of permeating STSE educational ideas. For instance, teaching strategies such as the question chain strategy [9] and problem-based learning [10], both grounded in the STSE philosophy, can be adopted in the classroom.

In addition, extracurricular activities, as a bridge for students to connect theory with practice, should be reasonably utilized to help students extend classroom teaching and conduct extracurricular penetration. Because they have greater openness, they can fully give play to students' individuality. Research-based learning under the STSE education concept mainly includes the following aspects: First, emphasize starting from interest, allowing students to choose topics they are interested in, such as environmental protection issues in life, small technological inventions, or themes related to humanities and history, extending the classroom to the real world to facilitate students' further in-depth perception and understanding; furthermore, learning by doing, through investigating community environments, recording life phenomena (such as the effects of garbage classification), allowing students to learn easily through hands-on practice instead of rote memorization [11]; secondly, cultivating students' sense of responsibility, for example, when studying the impact of mobile phone recycling on the environment, students not only learn technological knowledge but also become aware of the impact of human behavior on future social development; additionally, it allows students to deeply experience the scientific research process, just like scientists doing experiments, students must go through the process of "discovering problems--designing solutions--repeated verification." Although they will encounter failures, the sense of accomplishment from finally solving difficult problems will make them love exploration, giving play to students' subjective initiative; finally, helping students develop scientific thinking, learning to use data to speak and experiments to verify in investigations, gradually forming rigorous thinking habits, and deepening the understanding of the STSE concept through emotional experience.

Besides permeating in biology classes, activity classes, etc., it is also necessary to permeate STSE ideas in assignments. Reasonably permeating the STSE education concept in high school biology assignment design can not only promote the formation of a new assignment view but also make the consolidation process full of fun, no longer monotonous problem drilling [7]. Finally, multimedia teaching is also a necessary means in implementing STSE education. Using multimedia to produce exquisite and dynamic biological courseware allows students to understand abstract knowledge more intuitively.

4. Summary and Prospect

Today, with the rapid development of biology and information technology, teaching methods are also showing diversified development. We must use various available resources to better help students understand teaching content, and permeate the STSE education concept multi-directionally in and out of the classroom to help students fully understand biological knowledge. Overall, strengthening STSE education for students helps promote curriculum reform and can help improve students' biological scientific literacy, cultivating values of loving nature and cherishing life.

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