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Research on Improving and Assessing Higher-Order Thinking Skills among Secondary School Students in Biology

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Abstract: *This paper examines the factors influencing the cultivation of students' higher-order thinking skills in the context of current high school biology teaching practices. It discusses strategies and pathways for cultivating higher-order thinking skills in high school biology teaching. It proposes directions for developing higher-order thinking skills in high school students. The paper aims to provide a reference for the current basic teaching.*

Keywords: *higher order thinking skills; improvement; assess; senior high school students in biological teaching*

1. Introduction

In the context of an ever-changing social and technological landscape, the demand for talented individuals is subject to constant shifts and evolutions. The objective of education has evolved beyond the mere transmission of factual knowledge. Consequently, the current educational paradigm places a premium on the cultivation of abilities, with a particular emphasis on the nurturing of higher-order thinking skills. These skills have emerged as a crucial aspect of one's core competitiveness in the 21st century, serving as a vital benchmark for evaluating students' comprehensive quality. The cultivation of these advanced cognitive abilities enables education to better prepare individuals for the dynamic and demanding challenges of the modern world. This capacity encompasses analysis, synthesis, evaluation, and creativity and constitutes a pivotal component of students' scientific literacy. Specifically, higher-order thinking skills include, but are not limited to, critical thinking, innovative thinking, and problem-solving thinking, which are essential for students to adapt to future social changes and lifelong learning[1]. Given the distinctive disciplinary characteristics and wealth of instructional resources inherent to the biology curriculum at the high school level, this course has emerged as a pivotal avenue for the cultivation of students' higher-order thinking skills.

In traditional high school biology classrooms, an overemphasis on rote test-taking strategies often overshadows the systematic fostering of students' higher-order thinking. The challenge of guiding learners from superficial factual knowledge to profound, innovative thought has emerged as a pressing concern within the educational realm. This paper delves into the prevailing issues in high school biology instruction and explores innovative avenues for nurturing students' advanced cognitive skills within this subject, offering a roadmap for enhancing contemporary foundational teaching practices.

2. Influential factors of development and cultivation of higher-order thinking ability in senior high school students teaching

2.1 Uniformity of teaching methods

A considerable proportion of senior high school biology courses continue to adhere to traditional pedagogical approaches that prioritize mechanical memorization, which has been identified as a significant issue in the field of education. As a result, students frequently obtain only a cursory grasp of fundamental concepts, without developing a more profound comprehension or the ability to apply these concepts in practical situations.

The cultivation of higher-order thinking skills necessitates the implementation of diversified teaching methodologies, such as inquiry-based learning and project-based learning, among others. Such methodologies can effectively stimulate students' proactive cognition and exploratory drive, thereby

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fostering the development of their analytical, evaluative, and creative capabilities.

A considerable number of high school biology courses continue to adhere to the conventional teaching and memorization model. A reliance on this uniform pedagogical approach results in students acquiring only superficial knowledge, lacking both deep understanding and proficiency to apply their learning in a meaningful manner. In order to cultivate advanced cognitive skills, it is imperative to embrace a diverse array of educational strategies, encompassing inquiry-based learning (IBL) and project-based learning (PBL) methodologies.

Such methods can stimulate students' active thinking and desire to explore, thereby cultivating their analytical, evaluative, and creative abilities.

2.2 Lag in educational concepts

Traditional educational paradigms tend to prioritize the dissemination and rote memorization of knowledge while neglecting the nurturing of students' advanced cognitive capacities. This pedagogical strategy often proves ineffective in fostering autonomous and critical thinking, thereby impeding the development of students' higher-order cognitive abilities.

In some senior biology teaching, the influence of "examination-oriented education" persists. Teachers tend to prioritize students' test scores, which may result in the neglect of students' high-order thinking skills. For instance, during the review stage, teachers may assign a considerable number of practice questions and simulation papers, which may lead to an emphasis on mechanical memory and repetition training, while the cultivation of students' thinking skills may be overlooked.

2.3 Students' learning mentality

The learning mentality of the student is also a significant factor influencing the development of higher-order thinking skills. Some students prioritize academic achievement over the intrinsic motivation to explore and pursue knowledge, which is detrimental to the development of their higher-order thinking skills.

An individual's learning mentality is a significant factor influencing the growth of advanced cognitive capabilities. Some students are excessively focused on attaining high academic grades, which hinders their ability to engage in the intrinsic exploration and pursuit of knowledge. This preoccupation with grades impedes the development of their higher-order thinking skills.

2.4 Limitations of learning resources

The availability of learning resources is also a significant factor influencing the growth of students' higher-order thinking skills. In the absence of sufficient learning resources and a diverse array of educational opportunities, students are unlikely to be exposed to extensive knowledge domains or confronted with complex cognitive challenges. Furthermore, a mundane classroom environment exacerbates this issue.

In some areas or schools, students may not be able to access rich learning resources and diverse learning opportunities due to constraints. For example, they may not be able to participate in biological experiments, scientific competitions, etc., nor have access to the latest biological research results and academic developments.

2.5 The dull atmosphere in the classroom

The lack of stimulation in the classroom environment also impedes the growth of students' higher-order thinking skills. In an educational environment that lacks interaction and discussion, students are unable to develop their viewpoints and judgments. Furthermore, they are deprived of the valuable insights and inspiration that can be gained from engaging with others.

In some biology classes, the lack of interaction and guidance from teachers may result in a lack of engagement and expression among students. For instance, teachers may disseminate knowledge in a unilateral manner, discouraging students from posing questions and engaging in discourse. This may impede students' cognitive development and communication abilities.

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3. The current situation of cultivating students' higher-order skills in biology teaching in senior high school

3.1 Lack of scientific literacy of teachers and lack of students' subjective status

Some high school biology teachers adhere to a traditional pedagogical approach that places undue emphasis on the transmission and memorization of theoretical knowledge, fails to implement a student-centered teaching methodology, and neglects the cultivation of students' innovation abilities and creative consciousness. The evaluation system, which is guided by an examination-oriented education, places an excessive emphasis on test results, thereby neglecting the assessment of students' practical application abilities and innovative thinking. This ultimately results in exhibiting a lack of interest in learning of students, a deficiency in active questioning and problem-solving skills, and a limited improvement in their thinking skills. These factors collectively impact the quality and efficiency of teaching[2]. Furthermore, some high school biology instructors demonstrate a limited and superficial understanding of scientific literacy and an inadequate, rudimentary pedagogical expertise, which significantly impedes their capacity to effectively guide students in developing complex, higher-order thinking skills and fostering boundless creativity.

3.2 Lack of practical teaching, students' inquiry activities are superficial

Some educational institutions and regions have limited experimental facilities or insufficient attention from teaching staff, which is unable to meet the students' experimental requirements. This has resulted in the cancellation or simplification of experimental courses, with many experimental courses now being taught as "narrative courses". In the teaching of some experiments, there are often outdated experimental contents and simple and one-sided experimental processes, and students often merely follow the steps of the textbooks in the experimental process, lacking an in-depth understanding of the experimental principles. This makes it challenging to create opportunities for independent thinking and innovation, and even more challenging to solve practical problems through experiments. Consequently, there is less experimental exploration and thinking training.

3.3 Teaching theory is disconnected from actual life, making it difficult to create situations

The field of biology encompasses a vast array of abstract knowledge domains, and the body of biological knowledge is subject to rapid updates. Some students exhibit a limited capacity to comprehend abstract concepts and theoretical knowledge. Teachers frequently prioritize the explication and memorization of knowledge points, while overlooking the internal connections and practical applications of knowledge. This approach can impede students' capacity to construct a coherent knowledge system and develop critical thinking skills. The guidance provided to foster students' cognitive development in the classroom is often inadequate, resulting in their theoretical understanding remaining at a superficial level of learning.

The curriculum of biology in some secondary educational institutions is not aligned with the real-life experiences of students, resulting in a lack of engagement and interest in the subject. On occasion, the implementation of educational information technology is inadequate, with suboptimal integration and utilization of digital-age resources. This deficiency creates numerous obstacles for students in comprehending and analyzing novel scenarios, hindering their ability to proficiently apply biological knowledge in practical contexts.

3.4 The evaluation is not precise enough to differentially cultivate higher-order thinking skills

The evaluation method of high school biology teaching currently relies primarily on test scores, which fail to adequately assess students' higher order thinking skills. Additionally, the method lacks an examination of students' practical application abilities and innovative thinking. Furthermore, the development of students' thinking is not effectively reflected or improved, resulting in a tendency for students to become "test-taking machines" with limited independent thinking and exploration awareness. This ultimately affects the cultivation of higher-order thinking.

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4. Improving and assessing higher-order thinking skills among secondary school students of biology teaching

4.1 Updating the concept of education and highlighting the students' subjective status in the classroom

It is recommended that educators adopt a pupil-focused educational ideology, emphasizing the comprehensive nurturing of students' abilities and qualities rather than solely relying on the one-sided transmission of knowledge. In the context of teaching practice, educators must assume the dual roles of leaders and facilitators. They must also possess a nuanced understanding of students' cognitive processes and their potential for growth and development. Furthermore, they must demonstrate flexibility in their approach to teaching, employing a range of innovative strategies that align with the diverse needs of their students. The aim is to effectively stimulate students' intrinsic motivation and spirit of active exploration.

To achieve this objective, educators must discard the limitations of traditional didactic teaching methods and proactively construct a student-centered learning environment. The implementation of advanced models such as heuristic teaching and problem-oriented learning not only stimulates students' enthusiasm for learning but also promotes the improvement of their in-depth thinking and independent learning ability. Concurrently, it is of the utmost importance for teachers to emphasize the cultivation of students' critical thinking and innovative prowess. This should be done by encouraging students to pose inquiries, engage in autonomous analysis, and participate in imaginative, hands-on experiences.

While focusing on the development of students' knowledge and skills, educators must also consider the importance of students' emotional experiences and character formation. To attain this goal, a harmonious teacher-student bond must be cultivated, resulting in an inclusive and respectful learning atmosphere. Additionally, the use of strategies such as empathy-driven exchanges and psychological guidance can significantly aid in nurturing students' holistic character development and fostering positive psychological attributes.

To enhance the overall efficacy of teaching and elevate the professional standards of educators, educational institutions must augment the specialized training programs for biology teachers, fostering their ongoing professional development. The regular holding of teaching seminars and salons, with the participation of industry experts in the conduct of seminars and workshops, serves not only to update the scientific knowledge system of teachers but also to strengthen their teaching design and implementation capabilities. This ensures that teachers can maintain pace with the developments of the educational reform process and provide robust support for the comprehensive development of their students.

4.2 Optimizing the design of biological curriculum content and broadening the application scenarios of knowledge

It is incumbent upon educators to make optimal use of the curriculum resources at their disposal, including textbooks, teaching materials, and network resources. They should integrate pertinent knowledge points and cases and construct a comprehensive and nuanced knowledge system. By optimizing the design of biological experiment course content and incorporating higher-order thinking training, students can be effectively guided to propose hypotheses, design experiments, and analyze results in experiments, thereby improving their experimental abilities and critical thinking skills. For instance, in the experiment "Exploring the Conditions Affecting Enzyme Activity", educators can direct students to contemplate the variations in enzyme activity across different temperature and pH conditions, as well as the underlying reasons for these changes. Additionally, they can guide students in examining the rationale behind the selection of specific enzyme types and experimental conditions, fostering their analytical and comprehensive abilities[3].

It is imperative that educators integrate the subject matter of biology with the lived experiences of their students. This can be achieved through the analysis of case studies and the simulation of real-world scenarios, the design and implementation of exploratory and open-ended learning activities, and the guidance of students in developing independent critical thinking skills. This approach facilitates the development of student's abilities to link theoretical knowledge with practical applications and to apply theoretical principles to guide their practice. Additionally, it cultivates innovative thinking skills.

4.3 Innovative teaching strategies and methods, focusing on guiding thinking

(1) *Creating a problem situation, carefully designing questions, optimizing questioning skills, and activating students' thinking*

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Contextual teaching is of significant importance in stimulating the development of students' cognitive processes and expanding their application of knowledge. Teachers may integrate this approach by linking it to practical teaching scenarios and students' learning conditions, to create problem scenarios that facilitate students' contextualization. This process should guide and enhance students' analytical and judgment skills about these scenarios. For instance, when teaching fundamental biological concepts, teachers may pose challenging questions to prompt students to engage in deeper contemplation and comprehension. When designing these problem scenarios, teachers should prioritize openness and hierarchical structure to stimulate students' mental agility and creativity.

(2) *Adopting diverse teaching methods to stimulate interest in learning*

The incorporation of pedagogical techniques such as case analysis and project-based learning into the biological sciences curriculum has been demonstrated to foster students' intrinsic motivation and autonomy in learning. This approach enables students to develop their capacity for critical and creative thinking as they navigate the complexities of real-world problems. Furthermore, educators can facilitate student engagement in cooperative learning, which encourages cognitive interaction and discourse among students through group discussions and debates.

In a biology class, if the teacher employs a didactic approach to convey biological phenomena and laws, without facilitating students' exploration and analysis of the underlying reasons, it is challenging for students to develop their higher-order thinking skills. To illustrate, in the context of learning about the "laws of inheritance", if the instructor merely presents Mendel's pea-crossing experiment and the associated laws of inheritance without guiding the student to investigate the underlying principles, the student will remain at the level of mere recollection and will not develop a nuanced understanding or critical thinking.

① *Project-based learning*

It is incumbent upon educators to devise project assignments that are both stimulating and grounded in the curriculum of biology and tailored to the real-world circumstances of their students. Subsequently, educators should facilitate their students' navigation of these challenges through hands-on inquiry, strategic planning, and other practical methodologies. Additionally, they should promote teamwork among group members, encourage expression and communication, and engage in dialectic discourse to enhance students' awareness of teamwork and analytical judgment skills[4].

When teaching the "flow mosaic model of biofilms", if the instructor provides only a cursory overview of the structure and characteristics of the model, the student may remain at the level of mere recollection. Conversely, if the instructor employs an inquiry-based learning approach, wherein students construct their models and engage in discourse, comparison, and analysis of the merits and drawbacks of various models, students will be better equipped to grasp the concept and cultivate critical thinking and creativity.

② *Rational utilization of concept maps to facilitate the development of higher-order thinking*

In the field of biological education, educators may employ concept maps as a pedagogical tool to assist students in organizing and integrating biological knowledge, thereby fostering holistic thinking and comprehensive analytical skills. For instance, when imparting knowledge on cell biology, educators may utilize concept maps to delineate the structures and functions of cells in intricate detail. Such an approach can facilitate a deeper understanding among students regarding the interconnectedness and operational mechanisms of various cellular components, thereby enhancing their comprehension of this complex subject matter.

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③ *Utilizing information technology means*

It is incumbent upon educators to adeptly integrate multimedia and the Internet, along with other contemporary information technologies, transforming complex and difficult-to-understand concepts and theories into visually engaging, tangible spectacles that are easily accessible. This approach facilitates students' acquisition of a comprehensive understanding and firm grasp of the material. The incorporation of information technology not only markedly enhances the quality of teaching resources but also reinvents the classroom in ways unparalleled before, making learning both engaging and effective. For

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instance, students can "enter" the human body through virtual reality technology, witnessing the mysteries of blood circulation firsthand. Moreover, through methods such as data analysis and simulated experiments, students' abilities in data analysis and scientific reasoning are cultivated.

4.4 Strengthening evaluation and feedback, progressively enhancing students' higher-order thinking skills

(1) *Establishing a Diversified Evaluation System*

Educators may assess students' capacity for higher-order thinking and their advancement in this domain through a range of techniques, including classroom observation, homework evaluation, experimental operations, group discussions, and so forth. This necessitates not only the monitoring of students' test scores but also the prioritization of the cultivation and assessment of their practical application abilities and innovative thinking. By establishing a multifaceted and comprehensive evaluation system, educators can accurately assess students' cognitive abilities, including their capacity for critical thinking, creative thinking, and practical problem-solving. It is incumbent upon educators to observe and assess students' performance in classroom activities that require higher-order thinking, such as cooperative communication and problem-solving. Timely guidance should be provided to assist students in continuously developing their higher-order thinking skills. As part of the process evaluation, students are required to submit comprehensive experimental reports and deliver oral presentations, while actively participating in collaborative discussions and teamwork activities. These elements, coupled with the result evaluation, collectively contribute to a detailed record report that documents the cultivation and development of students' higher order thinking skills.

(2) *Focusing on feedback and evaluation, continuously cultivating and enhancing integrative capabilities and advanced cognitive training*

The reform of the new college entrance examination is designed to enhance the cultivation of students' critical thinking skills. It maintains rigorous standards for examination content and integrates knowledge into the situational design of problems. This approach situates students in authentic scenarios and challenges them to apply their knowledge in novel ways. In the context of the biology subject, this stipulation is reflected in the design of the examination questions. The biology test questions in the new college entrance examination exhibit a notable enhancement in openness, reflecting a greater emphasis on fostering students' divergent thinking and encouraging creative problem-solving approaches.

It is incumbent upon educators to prioritize the provision of constructive feedback and thorough evaluations that focus on the thought processes and outcomes of their students. In this way, educators can effectively assist learners in refining their cognitive strategies and methodologies, enabling them to make timely adjustments and improvements. Teachers are not merely disseminators of knowledge; they are also meticulous observers of their students' distinctive characteristics and evolving needs. It is therefore imperative that educators adopt a diverse range of assessment techniques, skillfully harnessing the motivational and directional aspects of evaluation. By moving away from the conventional teacher-centered evaluation model, educators can encourage students to engage in self-assessment and peer evaluation, thereby fostering a more dynamic and collaborative learning environment[5]. This approach can fully reflect the depth and breadth of students' thinking and stimulate their intrinsic motivation to learn.

The teaching of biology in senior high school plays a pivotal role in cultivating students' high-order thinking skills. It is a key area of focus for teachers, schools, and educational administrative departments. From the meticulous curation of instructional content to the sustained evolution of pedagogical approaches and the incremental enhancement of assessment frameworks, each phase aligns with the profound aspiration to foster advanced cognitive abilities. It is the convergence of these reforms and innovations that charts a trajectory toward the future for learners.

5. Conclusions

In light of the recently introduced curriculum reform concept, the cultivation of students' core literacy in high school biology teaching represents a pivotal aspect of the development of biological expertise. Teachers must adhere to an educational philosophy that is centered on the student. They must continuously optimize the knowledge system of biology courses, innovate teaching strategies and methods, and prioritize the role of evaluation and feedback in facilitating continuous improvement. This approach allows high school biology teaching to fully realize its educational value and gradually enhance the higher-order thinking skills of high school students.

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6. Suggestions for future teaching

In light of the evolving societal landscape and shifting talent demands, the cultivation of high-order thinking skills among high school students in the future should prioritize the following:

First, there is a need to refine and enhance the pedagogical approach to higher-order thinking ability training, with a particular focus on the cultivation of higher-order thinking skills among students of varying grades and levels. This should entail a more seamless integration of theoretical and practical elements. It is essential to reinforce the training and assistance provided to educators, particularly emphasizing the crucial role of experimental teaching in fostering high-order thinking skills. This should be accompanied by an enhancement of teachers' professional literacy and instructional competence in cultivating high-order thinking skills. Furthermore, it is vital to explore the integration of contemporary technological advancements, such as information technology and artificial intelligence, in the development of higher-order thinking skills. The use of multimedia resources, online platforms, and other digital tools allows educators to innovate their teaching methodologies and significantly enhance the overall efficacy of the learning experience. Fourthly, there is a need to reinforce the integration of disciplines and the undertaking of research with a view to practical applications. The research trajectory of interdisciplinary integration will prioritize practice and innovation. The integration of the intricate details of biology with the profound insights of other disciplines will not only enhance biological knowledge with a greater sense of depth and vitality, but also stimulate students' innovative thinking, expand their intellectual horizons, and cultivate their cross-disciplinary comprehensive thinking skills.

It is recommended that future research endeavors prioritize the establishment of a rigorous, holistic, and impartial evaluation framework and mechanism. The system should be designed to conduct a thorough and precise assessment of student's learning journey and the progression of their cognitive abilities, ensuring a comprehensive understanding of their academic growth and intellectual development.

By pursuing these initiatives with diligence, it is reasonable to anticipate that high school biology education will attain even more outstanding accomplishments in fostering students' higher-order thinking capabilities, ultimately leading to a more profound and enduring impact on their intellectual growth and academic success.

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