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Differentiated Teaching Strategies in Senior High School Biology Integrating IB Concepts: Taking the Cultivation of Students' Scientific Thinking as an Example

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Abstract: Based on the IB curriculum concepts of "inquiry-based learning", "interdisciplinary integration", and "differentiated assessment", this paper proposes differentiated teaching strategies centered on the cultivation of scientific thinking. By means of dynamic hierarchical grouping, contextualized case design, virtual simulation experiments, and a multi-evaluation system, a personalized learning path adapting to students with different cognitive levels is constructed. Research shows that this strategy can significantly improve students' experimental design ability and critical thinking.

Keywords: IB concepts; Differentiated teaching; Scientific thinking; Senior high school biology

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1. Introduction

The 2025 new curriculum standard for the college entrance examination biology clearly puts forward four core competencies: "life concepts, scientific thinking, scientific inquiry, and social responsibility", with experimental inquiry questions accounting for a sharp increase to 35% [1], marking the transformation of teaching evaluation from knowledge memory to higher-order ability assessment. However, traditional senior high school biology classrooms still have problems such as "one-size-fits-all" teaching, a lack of experimental practice opportunities, and insufficient interdisciplinary integration, which cannot meet the new curriculum standard's requirements for "solving problems in real contexts". In this context, the IB curriculum's concepts of "student-centered", "focus on inquiry process", and "emphasize interdisciplinary connections" provide strong support for teaching reform. Its differentiated assessment system and inquiry-based learning framework are highly consistent with the new curriculum standard's requirements of "teaching students in accordance with their aptitude" and "strengthening experimental inquiry", offering a reference path to solve current teaching dilemmas.

2. Theoretical basis of IB concepts and differentiated teaching in senior high school biology

2.1. Analysis of core IB curriculum concepts

2.1.1. Connotation and characteristics of inquiry-based learning

Inquiry-based learning is student-centered, emphasizing the construction of knowledge systems through active questioning, experimental design, data collection, and result analysis. Its core characteristics include problem-driven (learning activities centered on real problems), process-oriented (focusing on thinking processes rather than single answers), collaborative (encouraging learners to improve cognition through interaction), and reflective (requiring critical analysis of the inquiry process). In biology teaching, students can understand variable control and causal relationships through designing experiments on "the impact of environmental factors on enzyme activity" instead of passively accepting textbook conclusions [1].

2.1.2. Construction principles of support systems for students at different levels

The IB curriculum support system follows the dual principles of "hierarchical progression" and "personalized adaptation". Hierarchical progression enables students with different abilities to participate in inquiry activities through preset learning tasks of varying difficulty. In the "genetic laws" unit, students at the basic level can understand the law of segregation through a card simulation of Mendel's experiments, while advanced students analyze complex cases of linked inheritance of multiple genes. Personalized adaptation emphasizes adjusting support strategies according to students' interests and cognitive styles, providing concept map tools for visual learners and model-making tasks for kinesthetic learners [2].

2.2. Necessity of differentiated teaching in senior high school biology

2.2.1. Current situation and causes of individual differences among students

Senior high school students' cognitive differences in biology manifest in: knowledge foundation (some have mastered junior high school genetics while others need to reconstruct cognition from the concept of genes); ability structure (students with strong spatial imagination quickly understand the DNA double helix structure [3], while those with outstanding logical reasoning are better at analyzing genetic maps); learning styles (field-independent students prefer independent inquiry, while field-dependent students rely on teacher guidance). Causes include innate genetic factors, differences in early educational environments, and non-intellectual factors such as differentiated learning motivation [4].

2.2.2 Challenges and limitations of traditional teaching models

A unified teaching rhythm fails to meet individual needs, leading to the phenomenon that "top students are not challenged enough and underachievers cannot keep up". In teaching "mitosis", if teachers only use static pictures, students with weak spatial imagination cannot understand the dynamic changes of chromosomes; supplementing 3D animations may cause information overload for basic-level students. The standardized evaluation system further exacerbates this contradiction, with score-oriented teaching forcing students to focus on memory-based knowledge while neglecting the development of scientific thinking.

3. Design of differentiated teaching strategies in senior high school biology integrating IB concepts

3.1. Differentiated teaching strategies based on students' multiple intelligences

3.1.1. Application of multiple intelligences theory in senior high school biology teaching

Gardner's Multiple Intelligences Theory classifies intelligence into eight types: linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic. Biology teaching can develop learning resources targeting different intelligence channels: linguistically intelligent students deepen understanding by writing popular science articles; spatially intelligent students observe organelle structures using VR technology; bodily-kinesthetic students master DNA replication through model making; naturalistically intelligent students participate in campus biodiversity surveys [5].

3.1.2. Design of differentiated teaching plans for students with different intelligence types

Taking the "energy flow in ecosystems" unit as an example: linguistic students design "popular science manuals on energy flow" to explain concepts in plain language; logical-mathematical students construct mathematical models to calculate energy transfer efficiency; spatial students visualize energy flow paths with flowcharts; bodily-kinesthetic students simulate energy transfer in food chains through role-playing; interpersonal students organize group debates on "the impact of human activities on energy flow"; intrapersonal students write reflection journals analyzing their ecological protection behaviors; naturalistic students conduct on-site investigations of campus energy flow [6].

3.2. Application strategies of inquiry-based learning in differentiated teaching

3.2.1. Hierarchical design and implementation of inquiry-based learning tasks

Task hierarchy balances cognitive complexity and openness. Taking the inquiry of "factors affecting enzyme activity" as an example: basic-level tasks involve "exploring enzyme activity changes by controlling a single variable (temperature)" with detailed experimental steps and data recording tables; advanced tasks add "designing comparative experiments to verify pH effects" [7] requiring independent selection of buffer concentrations; high-level tasks involve "proposing unvalidated factors affecting enzyme activity (e.g., surfactants) and designing inquiry plans" emphasizing innovation and feasibility assessment. Teachers present hierarchical requirements via "task cards", allowing students to choose initial levels based on self-assessment and challenge higher levels after completion.

3.2.2. Assignment and guidance of differentiated roles in group cooperation

Role assignment follows the principle of "complementary advantages", with each group including a recorder (good at organizing information), experimenter (strong practical ability), presenter (clear expression), and questioner (outstanding critical thinking). In "simulating Mendel's hybridization experiments", experimenters operate cards, recorders draw genetic maps, questioners analyze experimental error sources, and presenters summarize laws. Teachers rotate roles regularly to avoid ability solidification and record student performance through "role observation forms" [8].

4. Practice and challenges of differentiated teaching in senior high school biology integrating IB concepts

4.1. Differentiated teaching practice in large-class settings

4.1.1. Difficulties and breakthroughs in implementing differentiated strategies in large classes

Large classes (usually over 50 students) prevent teachers from focusing on individual needs, making differentiated tasks prone to formality. Breakthrough strategies include: dividing functional areas using the “learning center” model for students to rotate through activities by ability level; developing an “intelligent diagnosis system” for automatic grouping through pre-class tests [9] and pushing adaptive learning resources; training student leaders as “little mentors” to assist teachers in guiding basic-level students. In the “immune regulation” unit, the system divides students into three groups to complete tasks: “drawing immune cell relationship diagrams”, “analyzing vaccine mechanisms”, and “designing new vaccine development plans”. Little mentors answer basic group questions while teachers focus on guiding advanced groups [10].

4.1.2. Practical exploration of information technology-assisted differentiated teaching

Information technology enables “scalable personalization”. Intelligent teaching platforms record student operation trajectories, analyze cognitive patterns through machine learning algorithms, and support teachers in adjusting teaching strategies. In virtual experiments on “neural regulation”, the system pushes targeted micro-courses based on students’ error types; online discussion areas automatically cluster similar questions through keyword analysis, allowing teachers to answer common doubts in batches.

4.1.3. Case analysis: Successful practice of differentiated teaching in large-scale biology classes

In teaching “stability of ecosystems”, teachers adopted the “hierarchical tasks + intelligent platform” model: basic-level students watched micro-courses to learn the concept of “resistance stability” and completed basic question banks; advanced students participated in online collaborative tasks of “designing grassland ecological restoration plans” with the platform displaying group progress and contribution in real time; high-level students analyzed “the impact of alien species invasion on stability” and submitted literature review reports. The platform automatically generated “ability development radar charts” showing students’ growth in knowledge understanding, data analysis, and innovative thinking. Post-tests showed that the standard deviation of student scores in each level was reduced by 1.2 units compared with traditional teaching, proving that differentiated strategies effectively narrowed ability gaps [11].

4.2. Adjustment of differentiated teaching under standardized examination backgrounds

4.2.1. Impact of standardized examinations on differentiated teaching and response strategies

Standardized examinations emphasize knowledge coverage and problem-solving skills, easily leading differentiated teaching to shift toward “examination-oriented training”. Response strategies include: decomposing examination requirements into differentiated goals (basic-level mastering “basic genetic map analysis methods”, advanced-level identifying “complex genetic patterns”, high-level designing “genetic disease screening plans”); developing “examination-oriented inquiry tasks” [12] (e.g., training data collection and processing abilities through experiments on “exploring the impact of environmental factors on population quantity” to directly correspond to experimental design questions in examinations); establishing “examination literacy files” to record students’ performance in “question-reading speed”, “key information extraction”, and “answer standardization” for targeted strengthening of weak links [13].

4.2.2. Balance between differentiated teaching and standardized examination goals

Balance requires grasping both "solid foundation" and "ability improvement". In reviewing "cell metabolism", teachers designed differentiated tasks: basic-level students completed fill-in-the-blank questions on "material changes in the three stages of aerobic respiration" to consolidate core concepts; advanced students analyzed "the biological significance of differences in anaerobic respiration products" to develop explanatory abilities; high-level students "compared respiratory differences among different tissue cells" to develop comprehensive application abilities. All tasks embedded high-frequency examination points (ATP production sites, energy calculation) to ensure differentiated teaching did not deviate from examination directions. Mock tests showed that the differentiated teaching group had an 18% higher score rate on "comprehension and application" questions than the traditional group, proving the effectiveness of the balance strategy.

5. Evaluation and improvement of differentiated teaching effects in senior high school biology integrating IB concepts

5.1. Construction of teaching effect evaluation index system

5.1.1. Quantitative evaluation indicators for scientific thinking cultivation effects

Quantitative indicators include critical thinking, creative thinking, and systematic thinking, scored using a Likert five-point scale. For example, the critical thinking scale includes three sub-dimensions: "problem identification", "evidence evaluation", and "conclusion derivation", with 5 statements per dimension for students to rate from 1 point to 5 points [14].

5.1.2. Qualitative evaluation indicators for differentiated teaching implementation process

Qualitative indicators focus on the adaptability and dynamic adjustment ability of teaching strategies, including the rationality of task hierarchy, effectiveness of support strategies, and timeliness of evaluation feedback. Data are collected through classroom observations, teacher reflection journals, and student interviews. Observation records detail how teachers respond to advanced-level students' questions such as "whether epigenetics affects Mendel's laws" to analyze whether guidance strategies promote in-depth learning [15].

5.2. Empirical analysis and feedback of teaching effects

5.2.1. Analysis of teaching effects based on empirical data

Empirical data include pre-test and post-test scores, classroom participation records, and work quality ratings. In the "gene expression" unit, the average pre-test score rate was 62%, increasing to 78% in the post-test (top students from 71% to 89%, basic-level students from 53% to 67%) (**Table 1**).

Table 1. Comparison of Classroom Behavior Observations Before and After Differentiated Teaching

Behavioral Indicators	Before Implementation	After Implementation	Change Rate
Number of student-initiated questions per class	1.2 times	3.9 times	+225%
Proportion of ineffective arguments in group discussions	35%	20.6%	-41%

5.2.2 Feedback and application of teaching effect evaluation results

Evaluation results are fed back through "tripartite meetings": school administrators adjust teacher training priorities based on comprehensive scores; teaching and research groups optimize task design for common problems; teachers develop personalized guidance plans based on individual feedback. One teacher adjusted the high-level task of "energy flow in ecosystems" from "calculating energy transfer efficiency" to "designing plans to improve farmland energy utilization" and introduced agricultural expert lectures as scaffolding. Subsequent evaluations showed a 3-fold increase in students' innovative proposals [16].

6. Conclusion

By integrating IB curriculum concepts, this paper constructs a system of differentiated teaching strategies in senior high school biology centered on scientific thinking cultivation. Research confirms that dynamic hierarchical grouping can accurately match students' cognitive differences, virtual simulation experiments effectively improve experimental inquiry abilities, and interdisciplinary case design significantly enhances knowledge transfer and problem-solving skills. Under the background of the 2025 new curriculum standard strengthening core competency assessment, this strategy not only provides a practical paradigm for transforming from "knowledge-oriented" to "competency-oriented" teaching but also achieves the consistency of "teaching, learning, and evaluation" through a multi-evaluation system.

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