An Exploration of the Application of Stage-Cycle Intelligent Teaching Reform in Microbiology

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Abstract: This paper discusses the application of stage-cycle intelligent teaching, beginning with an introduction to the concept of both the Microbiology course and stage-cycle intelligent teaching. The paper analyzes the importance of applying stage-cycle intelligent teaching to the field of microbiology and, based on the specific characteristics of the Microbiology course, proposes practical examples of applying this teaching method. The study provides theoretical knowledge for the training of microbiology talents and contributes to improving the effectiveness of Microbiology course instruction.

Keywords: Microbiology; Stage-Cycle Intelligent Teaching Method; Teaching Practice.

1. An Overview of Stage-Cyclic Intelligent Teaching in Microbiology

In the teaching of Microbiology, the reform of traditional teaching methods through the application of stage-cycle intelligent teaching optimizes and innovates the existing instructional approach. Under this new teaching method, students find the learning process clearer and easier to understand. This not only helps students master the course content but also strengthens the development of their self-learning ability, critical thinking, and innovative consciousness. How to apply stage-cycle intelligent teaching to the practical teaching of Microbiology is a crucial issue that educators need to address.

1.1 Overview of Microbiology

Microbiology is a fundamental subject in life sciences and medical disciplines, focusing on the study of microorganisms such as bacteria, fungi, viruses, and archaea, including their structure, function, metabolism, genetics, and interactions with the environment and hosts. As a discipline that emphasizes both foundational theory and practical application, its curriculum covers key areas such as microbial taxonomy, physiology and biochemistry, molecular genetics, environmental microbiology, pathogenic microbiology, and industrial microbiology techniques. Offering a microbiology course is crucial for cultivating interdisciplinary talent. The teaching of this course should emphasize the integration of theory and practice, enabling students to not only understand theoretical concepts in microbiology but also acquire practical skills and experimental methods. Strengthening hands-on teaching helps foster students' problem-solving abilities[1].

1.2 Overview of the Stage-Cyclic Intelligent Teaching

The Stage-Based Cyclical Intelligent Teaching Method is grounded in the fundamental principles of systems theory, informatics, pedagogy, physiology, psychology, and philosophy. Based on intelligent teaching theory and in conjunction with the curriculum syllabus and the nature of the discipline, this teaching method focuses on cultivating students' thinking abilities, learning abilities, and innovation capabilities. It centers around intellectual development and enhancing cognitive training. Applying the Stage-Based Cyclical Intelligent Teaching Method to microbiology teaching can promote educational reforms, improve the quality of course instruction, and enhance the overall learning experience.

1.3 Core Framework of the Stage-Cyclic Intelligent Teaching

The Stage-Cyclic Intelligent Teaching Method is structured around a core framework comprising the following phases:

Stage Division and Cyclic Mechanism

Goal-Stratified Phases: Learning objectives are

tiered according to students' foundational knowledge and cognitive abilities (e.g., from basic understanding → integrated application → innovative research), aligned with key microbiology topics (e.g., microbial taxonomy → metabolic engineering → synthetic biology).
Knowledge Input Phase: Personalized learning content is delivered via multimedia resources (such as animations and virtual simulation labs) and intelligent tutoring systems, including reinforcement of weak areas and recommendations of cutting-edge literature.
Practice Reinforcement Phase: Progressive training in operational skills and scientific thinking is achieved through a combination of virtual laboratories (e.g., aseptic techniques, gene editing simulations) and hands-on experiments.
Feedback Optimization Phase: By analyzing learning behavior data (e.g., quiz accuracy, experiment duration) and employing AI-based diagnostics, teaching stra tegies are dynamically refined, initiating the next learning cycle.
Intelligent Features
Dynamic Adaptability: Based on real-time student performance, personalized learning paths are generated (e.g., emphasizing theoretical supplementation or experimental enhancement).
Precision Intervention: Learning bottlenecks are identified, enabling the delivery of targeted micro-lessons or interactive exercises[2].
Competency Profiling: A multidimensional capability map is constructed across theoretical knowledge, practical skills, and innovative thinking to inform long-term talent development plans.
Teaching Advantages

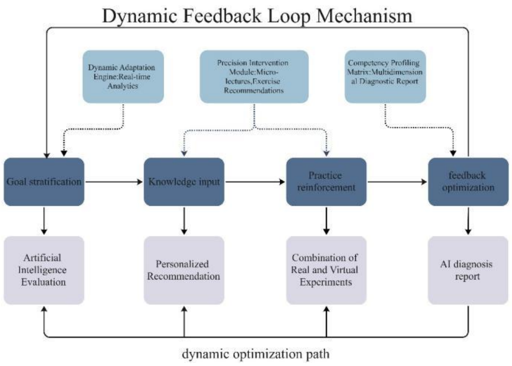

Figure 1. Dynamic Circulation Mechanism of the Stage-Cyclic Intelligent Teaching

1.4 Core Advantages of the Stage-Cyclic Intelligent Teaching

Overcoming Linear Instructional Constraints: Students can iteratively progress according to individual needs, achieving both knowledge consolidation and skill expansion.
Enhancing Autonomous Learning: Intelligent tools reduce repetitive instructional tasks, allowing educators to focus on guiding higher-order thinking.
Strengthening Research Integration: Real-world scientific problems (e.g., investigating mechanisms of antimicrobial resistance) are gradually introduced in the learning cycle to cultivate the ability to address complex issues.
The Stage-Cyclic Intelligent Teaching presents a learner-centered instructional model that systematically integrates theory with practice, emphasizes iterative learning, and leverages intelligent technology for precision teaching. Its core advantages are outlined below:
Personalized Learning Beyond Linear Constraints
Unlike traditional linear instruction, Stage-Cyclic Intelligent Teaching accommodates individual learning differences by setting progressive stages such as foundational, applied, and innovative learning goals. This allows students to enter at appropriate levels or revisit weaker components without being limited by uniform pacing.
For instance, in microbiology, learners can repeatedly engage with virtual simulations (e.g., PCR experiments) to enhance their technical skills, while more advanced students proceed directly to research-oriented tasks.
Integration of Theory and Practice
Each phase of the cycle blends conceptual learning with practice-based validation, enabling students to transition from theoretical understanding to real-world application. This tiered structure supports long-term skill development and critical thinking.
Example: A student may first explore bacterial metabolic pathways through multimedia content, then simulate experiments in a virtual lab, and finally optimize strains in an actual fermentation project.
Data-Driven Feedback and Adaptive Instruction
Real-time data analytics and AI-powered diagnostic tools allow for precise tracking of learning progress, helping instructors identify and address individual learning bottlenecks effectively.
The role of educators is redefined from knowledge transmitters to facilitators of higher-order learning, supported by digital tools that

automate routine feedback and enable a focus on cognitive development, such as scientific reasoning and critical analysis.

Promotion of Autonomous and Lifelong Learning

The recurring feedback loops within PCTM enhance students' ability to self-reflect and self-regulate[3]. They learn to assess their own progress and make informed adjustments, fostering independent learning habits.

Moreover, exposure to cutting-edge advancements (e.g., CRISPR in microbial editing) through iterative learning cycles prepares students for continuous professional development in rapidly evolving fields.

Efficient and Scalable Resource Utilization

By integrating virtual simulations with physical laboratory experiences, the model ensures cost-effective training without compromising operational proficiency.

In large-class settings, intelligent systems can generate differentiated learning plans, enabling scalable yet personalized education.

1.5 Summary

Through the design of "tiered progression, intelligent diagnostics, and cyclic reinforcement," the Stage-Cyclic Intelligent Teaching Method aligns with the high practicality and rapid knowledge evolution characteristic of microbiology. It effectively enhances students' technical application capabilities and innovative thinking, while also providing educators with scientific tools for instructional management.

2. The Application of Stage-Based Cyclical Intelligent Teaching Method

Stage-cyclic intelligent teaching includes three phases: the exemplar phase, the reflective phase, and the self-learning and innovation phase. When applied to the teaching of microbiology, this method guides students in autonomous inquiry-based learning, helping them better master course knowledge and enhance their learning and critical thinking abilities.

2.1 Advantages of Applying the Stage-Cyclic Intelligent Teaching Method in Microbiology Education

Efficient Mastery of Experimental Skills: Cyclical training in high-risk or high-precision techniques such as aseptic operations and gene cloning enhances proficiency while reducing material waste and safety hazards.

Development of Complex Scientific Thinking: By engaging in multiple rounds of "literature review → experimental design → data analysis → result refinement," students simulate authentic scientific research processes.

Addressing Interdisciplinary Challenges: In subfields such as environmental microbiology and medical microbiology, cyclical integration of interdisciplinary knowledge—such as chemistry and medicine—helps students meet the demands of cross-disciplinary learning.

2.2 Application of the Stage-Cyclic Intelligent Teaching Method in Microbiology Education

2.2.1 Exemplar Phase

The exemplar phase is composed of three stages: the reading stage, the listening comparison stage, and the method revelation stage. In the reading stage, students engage in independent reading, through which they familiarize themselves with key knowledge points and understand the connections between different concepts in microbiology. They conduct self-assessments based on their existing cognitive framework to evaluate their learning abilities, cognitive levels, and thinking skills, thus laying a solid foundation for the next phase of learning.

In the listening comparison stage, the teacher explains the structure of microbiology knowledge, helping students grasp the main content of the course. Students compare what the teacher presents with what they have learned through independent reading.

In the method revelation stage, the teacher elaborates on their understanding of the textbook content, how to use reference materials, and the connections between different knowledge areas. This helps students clarify their learning strategies and methods[4].

For example, in the chapter on "Microbial Metabolism," the teacher should deeply analyze the textbook, move away from the traditional method of explaining the textbook's content in sequence, and integrate the material based on students' needs. Students should first read the content independently. Then, in the listening comparison stage, the teacher can explain concepts such as "Metabolism is divided into material metabolism and energy metabolism," where material metabolism involves synthesis and degradation, and energy metabolism includes energy consumption and energy production. The teacher emphasizes how these two types of metabolism are interconnected, such as energy-consuming metabolism being involved in biosynthesis and energy-producing metabolism in catabolic processes. By drawing from students' prior knowledge of high school biology, the teacher leads students to learn microbial metabolism from the perspective of energy metabolism, introduces concepts such as chemotrophic autotrophic microorganisms, chemoheterotrophic microorganisms, and phototrophic microorganisms, and guides students to understand energy metabolism in these organisms. Additionally, energy-consuming metabolism is used to introduce knowledge related to cellular synthesis, movement, transport, and bioluminescence. Finally, the teacher explores microbial metabolic regulation through "enzyme synthesis" and "enzyme activity."

When explaining textbook knowledge in the listening comparison stage, teachers should emphasize the relationships between knowledge points and structure the knowledge logically.

For example, in the chapter on "microbial metabolism", based on the original textbook knowledge, the following knowledge arrangement can be made after processing the textbook: The knowledge can be divided into an introduction to metabolism, metabolic production, energy-consuming metabolism, and regulation of microbial metabolism. The introduction to metabolism includes the concept and classification of metabolism. Metabolic production includes biological oxidation, bio-oxidation in chemolithotrophic microorganisms, bio-oxidation in chemoheterotrophic microorganisms, and energy metabolism in phototrophic microorganisms. Energy-consuming metabolism includes the synthesis of cellular materials and other energy-consuming metabolic processes. The regulation of microbial metabolism includes the regulation of enzyme synthesis and the regulation of enzyme activity. By organizing the knowledge of microbial metabolism in a logical way and using case-based teaching, students can integrate what they have learned with the new knowledge of this chapter, grasp the relationships between different pieces of knowledge, and quickly understand new concepts, thus laying a solid foundation for the next stage of learning.

2.2.2 Reflective Phase

The reflective phase consists of three stages: the thinking stage, the debate stage, and the summary stage. First, in the thinking stage, the teacher plays an essential guiding role. After the exemplar teaching, students have gained a basic understanding of the lesson. The teacher designs reflective questions based on students' cognitive levels, the course content, and the teaching syllabus. These questions prompt students to engage in deeper reading and to think critically about the textbook content, the teacher's approach, and how to apply the knowledge.

To encourage active thinking, the teacher can ask random questions to assess students' understanding, analyze the learning situation, and guide further inquiry[5]. For example, in the topic of "Nutrient Transport in Microbial Cells," the teacher can ask questions to guide students in thinking about the concepts of microbial cells, whether there is a concentration gradient for the entry and exit of nutrients, whether carriers and energy are required, and whether there are competitive inhibition phenomena, in order to explore the course content. To ensure that every student participates in the critical thinking process and summarizes the course content, the teacher should strengthen attention and guidance. This can be done by randomly asking questions to assess understanding, encouraging students to think and explore, and fostering their learning and cognitive abilities.

Next, in the debate stage, students are encouraged to express their thoughts. After the thinking phase, students may have their own views and interpretations of the lesson. The teacher should encourage them to share their ideas and list the different opinions.

Finally, in the summary stage, the teacher summarizes the lesson's key points. After the thinking and debate stages, the teacher has a clearer understanding of students' grasp of the material. Positive feedback should be given to students who offer clear and accurate interpretations, while any misunderstandings should be addressed. The teacher should further analyze difficult concepts, providing more detailed explanations to reveal the underlying principles and rules, ensuring that students fully understand the material. For instance, in the chapter on "Infection" students might present different viewpoints, such as "concepts, infection outcomes, infection pathways, the impact of the environment on pathogenic microorganisms, and pathogenic mechanisms" or "concepts, infection pathways and methods, pathogenic mechanisms, infection outcomes, and environmental effects on pathogens." The teacher can guide students through the problem-solving process, following the three steps from philosophy—posing the problem, analyzing it, and resolving it. This approach allows students to understand infection pathways and ultimately devise prevention and control measures, such as interrupting the transmission routes of infections.

By posing, analyzing, and solving problems, the teacher helps students understand the course content more effectively.

2.2.3 Self-directed Learning and Innovation

After the example and reflective thinking stages of the teaching process, students have generally grasped the course content and developed certain learning and thinking abilities. At this stage, teachers should guide students toward self-directed learning and innovation, encouraging them to reconstruct the knowledge structure of the textbook and form their own unique insights on the course material. To achieve this, teachers can design learning tasks that prompt students to apply the knowledge and methods they have learned in practice, thereby cultivating their ability to learn independently. This process helps students clarify the relationships between different pieces of knowledge, master learning strategies, and apply knowledge and methods flexibly[6]. The goal is to enable students to make analogies and draw connections, thereby fostering their overall competency.

3. Conclusion

In summary, the staged cyclical intelligent teaching method, through its three phases—the exemplar phase, the reflective phase, and the self-learning and innovation phase—guides students progressively from basic to advanced understanding of course material. This cyclical progression enhances students' abilities in self-learning, critical thinking, and practical application. When applied to microbiology education, this approach can stimulate students' enthusiasm for learning, ignite their interest in microbiology, and strengthen their skill development, thereby improving the quality of course instruction and ultimately achieving the goal of cultivating interdisciplinary talents.

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