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A Study on the Reform of Inquiry-Based Experimental Teaching in General Biology Units Based on the 5E Teaching Model

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Abstract: As a core basic course for biology-related majors in universities, General Biology Experiments serves as a bridge connecting biological theoretical knowledge and practical application. At present, traditional experimental teaching is dominated by confirmatory experiments and suffers from problems including rigid teaching modes, fragmented content, passive student participation, lack of inquiry orientation, and insufficient innovation. It can hardly meet the cultivation demands for innovative and applied biological talents in the new era. Built on constructivist theory, the 5E teaching model is a closed-loop teaching process consisting of five links: Engage, Explore, Explain, Extend and Evaluate. It attaches great importance to students' subjectivity and inquiry-based learning, and is of great significance for improving experimental-teaching quality. Taking unit experimental teaching of General Biology as the entry point, this paper elaborates on the connotation and application value of the 5E teaching model, and discusses reform strategies for inquiry-based experimental teaching in General Biology units based on the 5E teaching model. It aims to offer new ideas for innovative reform of General Biology experimental teaching in institutions of higher education.

Keywords: 5E teaching model; General biology; Unit teaching; Inquiry-based experiment; Teaching reform

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1. Introduction

General Biology Experiments is an introductory core practical course for students majoring in science education, biological science and other related majors in universities. Its main task is to help students master basic biological knowledge, cultivate their scientific inquiry thinking, and improve their experimental-operation abilities. It acts as a bridge linking classroom theories and biological scientific-research practice [1]. With the continuous advancement of higher-education reform, previous experimental-teaching modes are in urgent need of all-round reform and innovation. The 5E teaching model is a mature constructivist teaching paradigm. It embeds inquiry-based learning into step-by-step, closed-loop teaching links, conforms to the practical and inquiry-oriented curriculum features of biology experiments, and exerts favorable effects

in improving the quality of inquiry-based experimental teaching in General Biology units and boosting the development of students' comprehensive qualities [2]. Therefore, while grasping its connotation and application value, we should actively explore effective practical paths, so as to comprehensively enhance teaching outcomes and further improve the talent-cultivation quality for biology majors.

2. Connotation of the 5E teaching model

The 5E teaching model is a systematic teaching model proposed on the basis of constructivist learning theory and inquiry-based learning theory. Put forward by the Biological Sciences Curriculum Study team in the United States, it derives its name from five core teaching links: Engage, Explore, Explain, Extend and Evaluate, whose English names all start with the letter E. It is a classic teaching model suitable for science-subject experimental teaching [3]. Breaking the traditional one-way teaching mode featuring teacher dominance and passive student reception, this model takes highlighting students' principal position in learning as its core. Through closed-loop and step-by-step teaching procedures, it guides students to independently complete the inquiry, construction, extension and consolidation of knowledge, so as to achieve teaching objectives in knowledge mastery, competence improvement and thinking cultivation [4].

Among the five core links of the 5E teaching model, the Engage link serves as the teaching-preparation part. It mainly arouses students' interest in inquiry. Teachers usually create teaching scenarios via real-life situations, scientific-research hot topics and cognitive conflicts, put forward core inquiry questions, connect prior knowledge with new knowledge, and awaken students' awareness of inquiry. The Explore link constitutes the core of the whole teaching model. It emphasizes students' independent practice and exploration, and guides students in groups to independently design schemes, carry out operations, collect data, as well as discover and solve problems, so that they can gain inquiry experience in practice. The Explain link belongs to the knowledge-construction stage. Students report inquiry outcomes and illustrate experimental procedures; teachers analyze and organize core knowledge to enable students to construct knowledge systematically. The Extend link focuses on knowledge transfer and innovative application. Centering on core in-class knowledge points, it designs extended inquiry tasks and breaks the limits of classroom teaching. The Evaluate link is the summary-and-promotion stage. It adopts a diversified evaluation method combining process-oriented and summative assessment to conduct all-round assessment of students' academic achievements and competence development, builds a teaching closed loop, and thus improves the scientific nature and effectiveness of teaching [5].

3. Application value of the 5E teaching model in inquiry-based experimental teaching of general biology units

3.1. Reconstruct the system and solve practical difficulties

Traditional General-Biology experimental teaching lacks systematic unit-oriented design. Most experimental content is independent confirmatory experiments for scattered knowledge points without logical connections between them. After finishing experiments, students can only master isolated operational skills and can hardly form a complete biological-knowledge system, which leads to the phenomenon of "learning a little while forgetting a little and knowledge disconnection". The 5E teaching model carries out holistic teaching design centering on unit themes, thoroughly changing the fragmented experimental-teaching mode. In actual

implementation, teachers integrate teaching objectives and content, take inquiry activities as carriers, and reflect correlations between structure and function [6]. Meanwhile, core unit questions are introduced into links including Explore, Explain and Extend. This can deepen students' knowledge and understanding and broaden their unit-related knowledge scope. Furthermore, unit-based and systematic teaching design can connect scattered experimental knowledge points and operational skills, helping students sort out knowledge logics and build systematic biological thinking. It realizes the shift from learning single-experiment operations to constructing systematic unit knowledge, and effectively addresses the problems of knowledge fragmentation and poor systematicness in traditional teaching.

3.2. Highlight students' principal position and cultivate their literacies

In view of practical realities, previous General-Biology experimental teaching mainly adopted the fixed workflow of "teacher explanation + demonstration operation + student replication". In class, students stay in a passive-reception state. They can mostly acquire basic operations, while their scientific-research inquiry competence and logical-thinking ability can hardly be cultivated. The 5E teaching model thoroughly transforms the traditional one-way teaching mode. It fully grants the right of independent inquiry to students and gives full play to their principal role in classroom activities. In the core Explore link, students work in groups to independently complete scheme design, material selection, procedure optimization, data collection and error analysis. Throughout the whole process, they discover, discuss and solve problems on their own [7]. Among them, the Engage link can stimulate students' desire for inquiry; the Extend link helps students break away from misconceptions derived from textbooks, conduct creative explorations by focusing on cutting-edge scientific research, and boost their innovative-ability development. In-depth application of this model in teaching can effectively foster students' capabilities in independent inquiry, teamwork, logical analysis and innovation, help them develop sound scientific literacy for biological research, and meet the talent-cultivation requirements for biology majors in the new era [8].

4. Reform strategies for inquiry-based experimental teaching of general biology units based on the 5E teaching model

4.1. Ground in unit themes and precisely create scenarios for classroom engagement

As the key to activating students' thinking and launching unit-oriented inquiry teaching, the Engage link exerts a direct influence on overall teaching outcomes. Previous experimental-teaching introductions mostly relied on verbal guidance and lacked fun. Accordingly, teachers should innovate the introduction link under the 5E teaching model. In particular, diversified scenarios should be created according to students' cognitive rules, real-life realities and discipline frontiers, centering on major unit-inquiry questions [9]. First of all, sort out units in General-Biology textbooks, identify main units including cell structure, biological metabolism, genetic laws and ecosystems, and clarify teaching emphases and core inquiry objectives for each unit. Secondly, diversify scenario-creation forms. On the one hand, connect real-life phenomena to create life-oriented teaching scenarios. For instance, in the cell-osmotic-pressure unit, create life-based question scenarios combined with phenomena such as fruit-and-vegetable fresh-keeping and plant wilting, so that students can perceive the practical value of biological knowledge. On the other hand, connect hot topics in biological scientific research and cutting-edge disciplinary achievements to create innovative teaching scenarios. For example, in the genetic-variation unit, introduce hot topics such as gene editing and breeding technologies together

with relevant video resources to build a digital scientific-research scenario and broaden students' disciplinary horizons [10]. Furthermore, abandon superficial and memory-oriented questions, and precisely design inquiry-focused hierarchical questions centering on core unit knowledge points. Guide students to actively associate theoretical knowledge with experimental content, arouse their desire for independent inquiry, create a favorable classroom atmosphere for subsequent Explore links, and achieve the teaching effect of "stimulating interest via scenarios and guiding inquiry through questions".

3.2. Allow independent inquiry and implement student-oriented principal practical exploration

The Explore link constitutes the core of the 5E teaching model, and also serves as an important module for cultivating students' operational capabilities and inquiry thinking. Aiming at the problems of mechanized student operations and insufficient space for independent inquiry in traditional experimental teaching, teachers shall break the shackles of fixed experimental procedures and build classroom modes based on students' independent inquiry [11]. Before class, based on unit teaching objectives, simplify solidified experimental procedures, refrain from providing standardized operation workflows, and only specify core experimental objectives, safety specifications and basic principles, so as to reserve sufficient space for students' independent design. In class, adopt group-based cooperative inquiry: organize students into groups of 4-6 to carry out cooperative experiments. Within groups, students shall determine experimental schemes by themselves, select appropriate experimental materials, optimize experimental procedures, and independently complete the whole experimental process. In this process, teachers shall act as guides, observers and Q&A facilitators. Do not interfere with students' normal inquiry procedures, and offer guidance only when students encounter core problems or operational mistakes. Let students discover and solve problems by themselves [12]. In addition, permit and encourage students to conduct experiments via different approaches. For example, they may change partial experimental variables, and allow experimental errors or even experimental failures. Through whole-process independent inquiry, fundamentally transform students' passive-learning state, and comprehensively cultivate their capabilities in experimental operation, scheme design and problem inquiry.

4.3. Focus on interpretation of outcomes and facilitate students' systematic knowledge construction

The Explain link acts as a key connecting stage for sorting out inquiry outcomes, consolidating unit knowledge and completing knowledge construction. It links independent inquiry with subsequent extension, and represents the core step for realizing transformation from practical inquiry to knowledge internalization. In this link, teachers shall reserve sufficient time for presentation and communication. Guide individual students or student groups to display their experimental schemes, experimental procedures, experimental phenomena and inquiry conclusions, elaborate their inquiry thinking and major findings in detail, and actively introduce problems encountered in experiments as well as corresponding solutions [13]. Secondly, organize whole-class interactive seminars. Hold collective discussions targeting varied group experimental results, data errors and abnormal phenomena, compare pros and cons of different experimental schemes, analyze causes of experimental deviations, and trigger collisions of inquiry thinking. Finally, teachers deliver summarized intensive lectures. Combined with presentations from each group, sort out core knowledge points from the perspective of unit themes, elaborate scientific principles behind experiments, summarize general inquiry methods, answer questions raised by students during inquiry, and correct their cognitive biases and operational

mistakes, so as to help students construct in-depth knowledge.

4.4. Rely on unit core connotations and carry out hierarchical extended innovative inquiry

The Extend link expands teaching boundaries and focuses on cultivating students' innovative-application capabilities. In this link, teachers may design hierarchical extended tasks. For students with weak foundations, design basic extended tasks centering on transfer and application of textbook knowledge [14]. Taking cell-respiration unit experiments as an example, students can be guided to explore changes in plant respiration under different environmental conditions so as to consolidate core in-class knowledge. For high-ability students, design research-oriented extended tasks combined with disciplinary frontiers, scientific-research subjects and production realities, and guide them to conduct independent inquiry. Secondly, break the temporal-spatial restrictions of classroom teaching, and encourage students to carry out various independent-inquiry activities such as experimental expansion, investigation and research, and subject exploration after class at any time and anywhere. Meanwhile, guide students to connect unit knowledge with fields including production practice, modern agriculture, and biomedicine, and discover practical values of knowledge. For instance, apply knowledge from enzyme-property experiments to scenarios such as food preservation and industrial catalysis, so as to strengthen their professional awareness, cultivate their capabilities in knowledge transfer and innovative application, and further improve teaching outcomes.

4.5. Optimize evaluation system and build a diversified whole-process evaluation mechanism

Aiming at the traditional and one-sided evaluation modes in previous teaching, teachers may optimize evaluation systems under the 5E teaching model and build a diversified whole-process evaluation mechanism [15]. First of all, transform the previous result-oriented-evaluation-dominated mode, introduce process-oriented evaluation and implement it throughout the Engage, Explore, Explain and Extend links. Conduct evaluations focusing on students' performance in experimental inquiry, including situational thinking, question-raising speeches, experimental-scheme design, group-cooperation performance, operational standardization, data recording, outcome presentation, extended inquiry, and experimental reflection, so as to accurately grasp students' learning progress and comprehensive-quality development. Secondly, optimize result-oriented evaluation. Get rid of the single assessment mode relying on experimental reports. Take unit core contents as carriers, adopt diversified assessment forms including practical-operation examinations, written knowledge tests and subject reports, and mainly examine students' mastery of unit knowledge, comprehensive operational competence and inquiry-application capabilities. Furthermore, based on teacher comments, introduce multiple evaluation modes, including self-assessment and peer assessment. For example, organize students to reflect on their own inquiry activities; enable groups to mutually evaluate one another's cooperation and inquiry outcomes, so as to bring more ideological inspiration to students and promote their better learning and development.

5. Conclusion

To sum up, based on constructivist theory, the 5E teaching model can effectively improve the quality of General-Biology experimental teaching via systematic, closed-loop and inquiry-oriented teaching links. Therefore, teachers in general education should actively apply it to teaching practice, comprehensively

improve teaching quality, promote the development of students' comprehensive qualities, and cultivate more high-quality compound talents for society.

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