ISSN 2522-6398 Vol. 8, Issue 4: 213-220, DOI: 10.25236/FER.2025.080431

Teaching Reform of General Biology Based on Vocational Competency Development in Food Inspection and Testing Programs

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Abstract: *General Biology, as a foundational course in the Food Inspection and Testing curriculum, plays a critical role in laying the groundwork for subsequent specialized courses and supporting students' development of professional skills. However, in vocational colleges, its teaching practice is often characterized by monotonous theoretical instruction, insufficient practical application, and a disconnection from industry-relevant competencies. This study adopts a competency-based approach aligned with the occupational demands of food inspection and testing, and proposes a tripartite instructional model integrating "fundamental theory, job-specific skills, and project-based practice." Through course content restructuring, pedagogical innovation, and the reinforcement of practical modules, the study aims to achieve an organic integration of knowledge transmission and vocational ability cultivation. The findings demonstrate that this reform significantly enhances students' engagement and professional identity, while also improving their analytical and problem-solving capacities. This study provides valuable insights for curriculum reform in vocational education.*

Keywords: *General Biology; competency-based approach; vocational education; curriculum reform; food inspection and testing*

1. Introduction

As a foundational core course in vocational education programs for Food Inspection and Testing, General Biology plays a pivotal role in the professional training system. By systematically covering essential topics such as cell biology, molecular genetics, biological classification, and ecology, the course provides the theoretical underpinning and practical groundwork necessary for subsequent specialized courses, including microbiological testing techniques, food safety monitoring, and food biochemistry [1]. However, in the current context of vocational colleges, the teaching of General Biology is often hindered by unclear course positioning and a misalignment between instructional content and occupational demands, thereby significantly limiting the quality of talent cultivation.

From the perspective of differentiated development in vocational education, the construction of General Biology courses in vocational colleges faces a dual dilemma. On one hand, many institutions directly adopt general education curricula from academic universities, placing excessive emphasis on the systematic and comprehensive nature of disciplinary knowledge, while neglecting the competency-based orientation fundamental to vocational education [2]. On the other hand, the teaching content lacks effective integration with professional standards relevant to food inspection roles, making it difficult for students to translate foundational knowledge into vocational competence. Empirical studies show that over 60% of students find the course abstract and difficult to grasp, and perceive it as lacking relevance to their future career development [3], resulting in low learning motivation and poor instructional outcomes.

With the deepening implementation of the National Vocational Education Reform Implementation Plan, vocational curriculum reform has entered a phase of substantive development. The policy clearly advocates for the alignment of curriculum content with occupational standards, and the integration of teaching processes with real-world production processes [4], thereby pointing the way forward for the reform of General Biology. Careers in food inspection demand core competencies such as microbial identification and analysis, standard laboratory procedures, and biosafety management [5]—competencies

ISSN 2522-6398 Vol. 8, Issue 4: 213-220, DOI: 10.25236/FER.2025.080431

that must be cultivated upon a solid foundation of biological knowledge. Consequently, restructuring the curriculum based on vocational competency has become an urgent imperative in the context of educational reform.

Teaching practice reveals three primary challenges that vocational students encounter in foundational science courses: first, difficulty in cognitively linking biological concepts to food inspection practices; second, limited ability to translate theoretical knowledge into practical skills; and third, a lack of professional identity and understanding of future career pathways [6]. These issues stem from the traditional "discipline-centered" teaching paradigm, which fails to accommodate the distinctive features of vocational education and students' cognitive development. Therefore, it is imperative to explore reform pathways for foundational courses that are congruent with the principles of vocational education.

In recent years, theoretical advancements in vocational curriculum development—such as the "work-process-based curriculum design" approach [7-8]—have emphasized the use of typical workplace tasks as vehicles for the integrated development of knowledge, skills, and professional attributes. Concurrently, the growth of educational informatization has provided new technological tools to support curriculum reform. The application of modern instructional technologies, including virtual simulation and smart classroom environments, has effectively addressed practical constraints in traditional teaching, such as limited laboratory resources and monotonous instructional scenarios [9-10]. These theoretical and practical innovations offer valuable guidance for the reform of General Biology instruction.

Therefore, this study takes the Food Inspection and Testing program as a case study to explore a competency-oriented reform pathway for the General Biology course. By reconstructing course objectives, optimizing content modules, innovating pedagogical strategies, and reforming assessment mechanisms, the study aims to enhance the vocational relevance and instructional effectiveness of the course. It also seeks to provide a replicable and evidence-based model for foundational course reform in vocational education.

2. Objectives and Positioning of Curriculum Reform

2.1. Establishing a Three-Dimensional Curriculum Objective Framework

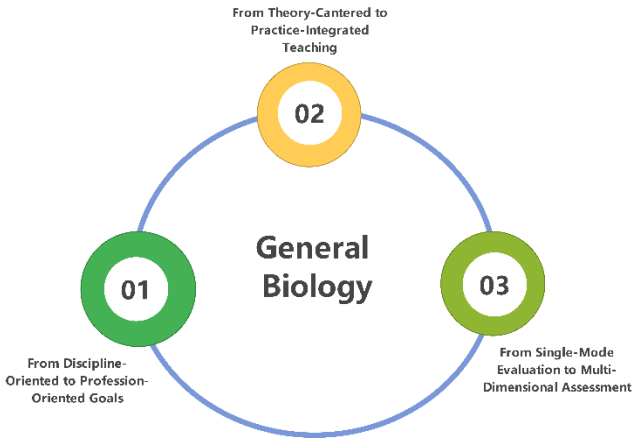

Figure 1: Three-Dimensional Curriculum Objective Framework.

In response to the vocational competence requirements of the Food Inspection and Testing major, this study proposes a three-dimensional curriculum objective framework encompassing knowledge, skills, and attitudes (as illustrated in Figure 1). This framework transcends the traditional knowledge-centered approach of foundational science courses and achieves three key transformations:

(1) From Discipline-Oriented to Profession-Oriented Goals

The curriculum objectives are closely aligned with the National Occupational Skill Standards for Food Inspectors (2022 edition), integrating fundamental biological concepts with typical workplace tasks in food inspection. For example, in the cell biology module, instruction emphasizes the relevance of cell structure to microbiological detection techniques in food, enabling students to apply cellular biology principles to explain the microscopic mechanisms of food spoilage.

(2) From Theory-Cantered to Practice-Integrated Teaching

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The reformed curriculum increases the proportion of laboratory instruction to 40%, establishing a three-tiered practical teaching system consisting of basic experiments, integrated training, and virtual simulations. Special attention is paid to cultivating fundamental laboratory skills such as microscopy and microbial slide preparation—skills that are frequently applied in food microbiological testing.

(3) From Single-Mode Evaluation to Multi-Dimensional Assessment

A diversified assessment system has been established, comprising theoretical examinations (30%), laboratory performance evaluations (40%), and vocational task-based assessments (30%). The vocational tasks simulate real-world scenarios, such as "Detection and Classification of Microorganisms in Food Samples," to holistically evaluate students' ability to apply biological knowledge in practical settings.

2.2. Developing Professionally-Oriented Competencies Driven by Job Requirements

According to the National Occupational Skill Standards for Food Inspectors and the competency-based training guidelines for food-related vocational programs, clear requirements are defined regarding the biological knowledge and technical skills expected of practitioners in food inspection roles. As a foundational course in professional competence development, General Biology must be precisely aligned with these job demands to ensure high relevance and practical value of the curriculum content (seen figure 2). Key capabilities to be cultivated include:

Figure 2: Professionally-Oriented Competencies Driven by Job Requirements.

(1) Microorganism Identification and Classification Competency

The knowledge including microbial contamination detection and interpretation are core tasks in food inspection. Students must be able to identify common foodborne microorganisms and understand their morphological characteristics, growth conditions, and biological features. The curriculum should enhance students' mastery of classification principles and diagnostic techniques for bacteria, fungi, and viruses, thereby laying a theoretical and technical foundation for advanced courses such as Food Microbiology and Food Safety Testing Techniques.

(2) Understanding of Cell Structure and Function

As the fundamental unit of biological systems, the cell's structure and function—particularly cell membranes, organelles, nucleic acids, and proteins—form the basis for comprehending microbial metabolism, growth, reproduction, and food spoilage mechanisms. This competency enables students to analyze practical issues such as food preservation, spoilage, and sterilization, and supports learning in applied disciplines like biochemistry and food processing.

(3) Basic Laboratory Skills

Accurate laboratory operations are integral to food inspection tasks, including microbial smearing, staining, microscopic observation, and sample pre-treatment. The course must ensure sufficient and standardized laboratory training, equipping students with essential skills in microscopy, slide preparation, and observation techniques, while also enhancing their capabilities in experimental design and data interpretation. Moreover, virtual simulation platforms can supplement physical experiments, improving interactivity and ensuring safety in the teaching process.

(4) Biosafety Awareness and Ethical Cognition

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Adherence to biosafety protocols and ethical standards is a fundamental requirement in laboratory work and microbial handling. The course should incorporate instruction on biosafety levels, protective measures, waste disposal, and professional ethics to foster a strong safety culture and professional responsibility among students. This ensures they can work efficiently and safely in future professional settings.

3. Curriculum Content Reconstruction and Modular Design

In the context of vocational colleges, the General Biology course must be reconstructed and modularized according to the practical demands of specific job positions, particularly to enhance students' professional competencies in key areas such as microbiological inspection and laboratory operations. The reconstruction of course content is closely aligned with the applied nature of the Food Inspection and Testing program, ensuring that students can effectively integrate theoretical knowledge with skill development throughout their learning process. Based on a competency-oriented pedagogical reform approach, the course content is divided into several modules, each focusing on the cultivation of job-related competencies. These include three core modules: Fundamentals of Biological Structure and Function, Biology and the Environment, and Laboratory Skills and Experimental Operations.

3.1. Fundamentals of Biological Structure and Function

This module introduces foundational biological concepts, including cell structure and function, cellular metabolism, and the basics of heredity. Upon completing this module, students are expected to understand the fundamental composition and life activities of living organisms. Special emphasis is placed on the physiological structures of microorganisms, such as cell walls, membranes, nucleic acids, and their associated metabolic processes. These topics provide essential theoretical support for comprehending microbial activity mechanisms in food, causes of spoilage, and microbial contamination control.

Positions in food inspection and testing require practitioners to have strong skills in microbial identification and analysis. Through this module, students will gain proficiency in identifying the morphological characteristics of bacteria, fungi, and viruses, and understand how microbial metabolic activities affect food quality and safety. Furthermore, students will develop a foundational understanding of microbial physiology and metabolism, enabling them to recognize and manage potential microbial contamination in food products and apply appropriate inspection and control strategies.

This module aims to help students master the basic structure and functions of cells, understand microbial metabolic and genetic characteristics, and cultivate their ability to identify microorganisms in food, laying the groundwork for subsequent courses in microbial detection.

3.2. Biology and the Environment

This module covers fundamental theories of microbial ecology, focusing on interactions between organisms and their environments. Students will explore how microorganisms survive and reproduce under various environmental conditions and their relationships with other organisms. The course further analyzes the impact of environmental factors on microbial growth and food quality. Topics include microbial ecological diversity, sources of environmental pollution, and their potential effects on food safety.

Food inspection professionals must possess environmental analysis capabilities and the ability to identify sources of contamination. Environmental factors play a critical role in microbial detection and food quality control. By studying the interactions between organisms and their environment, students will be able to recognize potential environmental sources of food contamination and understand how varying environmental conditions influence microbial growth in food, thereby improving their capacity for quality control and food safety evaluation.

The goal of this module is to introduce students to the ecological principles of microorganisms, deepen their understanding of environmental influences on microbial activity and food quality, and help them identify external contamination sources. It also aims to foster students' environmental adaptability and analytical skills for food quality assessment.

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3.3. Laboratory Skills and Experimental Operations

This module focuses on the development of hands-on experimental skills, covering topics such as microscopic observation of microorganisms, preparation of common culture media, and sample collection and processing. Students will gain proficiency in fundamental biological laboratory techniques and be able to apply them in practical settings for microbial isolation, cultivation, identification, and analysis. The instructional design emphasizes experimental activities integrated with theoretical learning. Students will practice microscopic identification of microbial morphology and structure, learn how to prepare and utilize various culture media, and develop the skills to extract and isolate microbial samples from food. Techniques for proper sample storage and processing will also be emphasized.

Personnel in food inspection and testing must demonstrate solid experimental competencies, including independent execution of microbial detection, sample analysis, and data interpretation. Through this module, students will master key laboratory techniques, enabling them to perform microbiological inspections in compliance with standard operating procedures, accurately conduct tests, and carry out preliminary analysis and reporting based on experimental data.

The aim of this module is to enhance students' experimental proficiency, particularly in microbial detection and food quality control. It emphasizes developing hands-on skills through laboratory practice, enabling students to competently perform microbial isolation, cultivation, and analytical procedures.

In the teaching of General Biology within vocational colleges, innovative teaching methods and strategies are essential for enhancing students' professional competencies and overall quality. As the demands of vocational education and skills training continue to rise, traditional lecture-based instruction has become increasingly insufficient in meeting students' practical learning needs. Therefore, it is imperative to integrate more effective, interactive, and competence-oriented teaching approaches into the reform of biology education. This study proposes several innovative methods aimed at enhancing students' learning outcomes and professional adaptability through a combination of classroom interaction, experimental instruction, and information technology.

4. Innovation in Teaching Methods and Strategies

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4.1. Problem-Based Learning

Problem-Based Learning is a student-centered instructional strategy that encourages autonomous learning through the exploration of real-world problems. In General Biology, instructors can design case studies relevant to food inspection and testing, such as "Analyzing the Causes of Food Spoilage" or "Rapid Microbial Detection in Food Samples." Students are encouraged to engage in group discussions, experimental design, and data analysis centered around these practical problems. For instance, in the "Food Spoilage Analysis" module, students may investigate the microbial causes of food deterioration, isolate and culture microbes, and examine how environmental variables influence microbial growth.

This method not only enables students to acquire fundamental biological knowledge but also cultivates their ability to apply this knowledge to solve practical problems. PBL significantly enhances students' active learning capabilities and fosters comprehensive skills such as teamwork, problem-solving, and innovative thinking—qualities that are vital in the field of food inspection and testing. The core advantage of PBL lies in the integration of theoretical knowledge with real-world applications, thus promoting practical skill development. By engaging in research based on authentic scenarios, students learn to perform scientific analyses, conduct experiments, and process data, thereby gaining valuable competencies for their future professional careers.

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4.2. Integrated Theoretical and Practical Instruction

The "Integration of Theory and Practice" approach involves the seamless combination of conceptual learning with hands-on experience. In the General Biology course, each theoretical concept is accompanied by corresponding small-scale experiments or demonstrations. For example, during the lesson on "Cell Staining," instructors guide students through staining procedures to help them visually and directly comprehend cellular structure. This approach addresses the common disconnect between theory and practice in traditional teaching, reinforcing students' understanding through experiential learning.

In the "Microbial Cultivation" module, beyond explaining cultivation conditions and key techniques, students are required to prepare culture media and observe microbial growth under various environmental conditions. This integrated approach allows students to acquire practical skills and develop scientific reasoning through direct engagement. The pedagogical strength of this method lies in its ability to consolidate students' grasp of core biological concepts while simultaneously fostering proficiency in laboratory techniques. Additionally, through inquiry-based exploration during experiments, students cultivate independent thinking and critical analysis—key traits for success in professional settings.

4.3. Integration of Information Technology in Teaching

With the rapid advancement of information technologies, digital instructional tools have become indispensable in modern education. In General Biology, virtual simulation platforms can be employed to conduct simulated experiments such as "Cellular Observation" and "Microbial Isolation and Cultivation." These platforms overcome the temporal and spatial limitations of traditional laboratory settings, offering students enriched and immersive learning experiences.

Virtual labs simulate real experimental procedures, allowing students to gain operational skills and familiarize themselves with laboratory environments and equipment prior to actual hands-on practice—thus reducing operational errors and safety risks. For instance, in the "Cell Observation" module, students can use virtual microscopes to examine different types of cells and explore how staining techniques affect cellular structure. In the "Microbial Cultivation and Isolation" module, students can simulate the process of cultivating, isolating, and identifying microorganisms, learning to assess microbial growth and its relationship with environmental factors.

The primary advantage of incorporating information technology lies in its ability to facilitate flexible, asynchronous learning. Students can access the virtual lab environment anytime and anywhere, thereby enhancing learning efficiency. Moreover, virtual simulations not only aid in mastering laboratory techniques but also enable students to experience a variety of experimental scenarios, strengthening their capacity to address real-world challenges. These tools provide a solid foundation for students' future careers in food safety and quality control.

5. Evaluation of Reform Outcomes and Student Feedback Analysis

Over the past two semesters, the pilot reform of the General Biology course has yielded promising results. By incorporating project-based learning, integrating theoretical and practical teaching elements, and leveraging digital instructional tools, the overall teaching quality has significantly improved. Simultaneously, students' learning experience and professional competence have been notably enhanced.

First, student satisfaction with the course has markedly increased in Figure 3. According to survey results, the overall satisfaction rate rose to 88%, compared to 85% before the reform. This substantial improvement reflects students' positive reception of innovative teaching methods, revised course content, and strengthened practical components. Many students noted that the course is now more closely aligned with real-world applications, facilitating a clearer understanding of future professional demands.

Second, the increased pass rate in laboratory assessments is a key indicator of the reform's effectiveness. The revamped experimental component emphasizes active student engagement and the cultivation of practical skills. The experiment pass rate exceeded 82%, compared to 78% prior to the reform. Through direct participation in hands-on experiments, students not only acquired essential technical skills but also developed a deeper understanding of the operational requirements in the field of food inspection and testing.

More importantly, students demonstrated improved performance in subsequent professional courses.

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In subjects such as Food Microbiology and Food Safety, students exhibited notable progress, particularly in experimental operations and the application of theoretical knowledge. The foundational understanding gained from General Biology has been effectively transferred to more advanced coursework, thereby enhancing curricular coherence and continuity.

In terms of student feedback, the majority expressed that the course is "more aligned with professional realities and helps to better understand future job requirements." Notably, many students reported a strong sense of accomplishment during the experimental sessions. This hands-on experience not only increased their interest in course content but also deepened their understanding and mastery of biological knowledge. Furthermore, students stated that practical exercises enhanced their sense of competence and boosted their confidence regarding future career development.

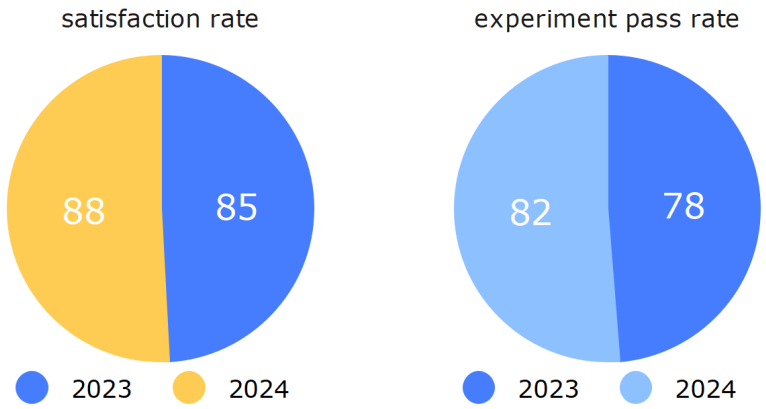

Figure 3. The satisfaction rate and experiment pass rate in the year of 2023 and 2024.

6. Conclusions

This study provides an in-depth exploration of the teaching reform of the General Biology course in vocational and technical colleges. Focusing on vocational competence development goals, a series of reform measures were proposed, including the reconstruction and modular design of course content, innovation in teaching methods, and the reform of the teaching evaluation system. The implementation of the pilot reform has yielded significant results, with a notable increase in student satisfaction and laboratory pass rates. Furthermore, students' performance in subsequent professional courses has also shown substantial improvement, particularly in terms of practical skills and the application of theoretical knowledge. However, despite the initial success of the reform, there remain several issues that need to be addressed. For instance, there is still a lack of adequate laboratory resources, some students exhibit weak self-learning abilities, and the depth and breadth of university-industry collaboration require further enhancement. In the future, teaching reforms should continue to focus on optimizing resource allocation, strengthening university-industry partnerships, improving the practicality and adaptability of the curriculum, and further developing students' self-directed learning abilities. These steps will ensure that students not only have a solid foundation in theoretical knowledge but can also quickly adapt to and excel in their professional roles. Overall, the teaching reform of the General Biology course, based on vocational competence development, is an important component of vocational education reform. It is a key strategy for enhancing students' comprehensive quality and professional adaptability. By continuously improving course content, teaching methods, and evaluation systems, the reform will better promote students' overall development and cultivate high-quality technical professionals who meet industry demands. This will contribute positively to the development of the food inspection and testing industry. In the future, we will continue to optimize the reform plan, deepen the integration of theory and practice, and provide a solid foundation and broader space for students' professional growth.

Acknowledgements

The work is supported by Innovation and Development Joint Fund of Natural Science Foundation of Hubei Province (No.2023AFD060), Natural Science Foundation of Hubei Province (No.2024AFB108),

Innovation and Entrepreneurship Education of Hubei University of Arts and Sciences (No.CX202408), and Science and Technology Research Project of Education Department of Hubei

ISSN 2522-6398 Vol. 8, Issue 4: 213-220, DOI: 10.25236/FER.2025.080431

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