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Integrating Labor Education into Medicinal Chemistry in Higher Vocational Education: A Curriculum Reform at Qingdao Technical College

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ABSTRACT

Background: In higher vocational biopharmaceutical education, Medicinal Chemistry is both a bridge between basic chemistry, pharmaceutical preparation, and pharmaceutical analysis and an important vehicle for cultivating responsibility for drug quality and disciplined professional work habits. The course nevertheless faces several persistent problems: broad content coverage within limited contact hours, insufficient practice-based learning, weak representation of authentic occupational processes, and difficulty translating the values of labor education into observable and assessable behaviors.

Methods: Taking the 2024 Medicinal Chemistry curriculum standard for the Biopharmaceutical Technology program at Qingdao Technical College as the institutional basis, this curriculum-design study employed policy and curriculum-text analysis, a review of relevant scholarship, occupational-task logic analysis, and curriculum mapping. The relationships among learning outcomes, teaching content, learning activities, and assessment evidence were systematically reconstructed. No unverified student achievement or teaching-effectiveness data were used.

Results: A four-chain alignment framework was developed to connect the occupational-task chain, knowledge–competence chain, professional work-practice chain, and assessment-evidence chain. Drug-class content was reorganized into five task domains: structural interpretation and information retrieval; physicochemical properties and storage/handling decisions; synthetic routes and impurity risks; quality standards and testing decisions; and innovative design and professional ethics. The proposed implementation system combines a complete aspirin synthesis and quality-evaluation project with occupational micro-projects on β-lactam antibiotic stability, omeprazole storage, and related topics. Within the existing assessment weighting of 50% theory, 30% skills, and 20% continuous assessment, diversified evidence is collected for knowledge, technical performance, compliance, integrity, collaboration, reflection, and innovation.

Conclusion: The proposed reform foregrounds the defining features of higher vocational education—occupational relevance, integration of theory and practice, school–enterprise collaboration, and the coordinated development of ethical responsibility and technical competence. It provides an implementable basis for subsequent action research and empirical evaluation.

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Introduction

Vocational education has a status equal to that of general education in China, and its curriculum must respond simultaneously to industrial demand, occupational competence, and students' holistic development. The Vocational Education Law of the People's Republic of China establishes the cultivation of highly qualified technical and skilled personnel, industry–education integration, and school–enterprise cooperation as legal requirements. The National Implementation Plan for Vocational Education Reform and the Opinions on Deepening the Reform of the Modern Vocational Education System further require programs and curricula to align with industrial needs and encourage schools and enterprises to participate jointly in talent development [1-4]. The Outline for Building a Leading Country in Education (2024–2035) likewise calls for an industry-integrated vocational education system and stronger practical, problem-solving, and social-adaptation capabilities among students [5]. In biopharmaceutical technology programs, these requirements ultimately concern whether students can understand material properties, comply with quality standards, identify drug-related risks, and assume responsibility for their operations and data.

Drug research and development, production, testing, storage, distribution, and use are all highly regulated. The Drug Administration Law of the People's Republic of China requires activities throughout the drug lifecycle to comply with laws,

regulations, standards, and technical specifications, and it requires relevant information to be authentic, accurate, complete, and traceable [6]. The 2025 edition of the Pharmacopoeia of the People's Republic of China, effective from October 1, 2025, is an essential statutory technical basis for pharmaceutical quality control [7]. Accordingly, Medicinal Chemistry in higher vocational education should not culminate merely in memorizing drug names, structural formulas, and structure–activity relationships. Students should also learn to translate structural and physicochemical knowledge into preliminary judgments concerning storage, testing, synthesis, impurity control, and quality communication.

Labor education provides an educational route for integrating knowledge, competence, and responsibility. In the Chinese vocational-education context, labor education refers to systematic learning through productive, service, and professional work activities, with attention to work values, practical competence, responsibility, and respect for standards. The Opinions on Comprehensively Strengthening Labor Education in Primary, Secondary, and Higher Education in the New Era require labor education to be incorporated throughout talent development, while the Guidelines for Labor Education in Primary, Secondary, and Higher Education (Trial) emphasize that vocational institutions should organize productive and service-oriented work in authentic or simulated occupational settings so that students develop quality awareness, innovation, cooperation, and social responsibility [8,9]. Work in pharmaceutical settings is not simply physical activity. Weighing, labeling, documenting, verifying, line clearance, waste disposal, and deviation reporting are all forms of professional work governed by regulation, standards, and ethics. If labor education remains limited to abstract expressions such as "pursuit of excellence" or "craftsmanship," students may find it difficult to translate these values into stable occupational behaviors.

The 2024 Medicinal Chemistry curriculum standard at Qingdao Technical College defines the course as a compulsory professional foundation course that integrates theory and practice and supports innovation and entrepreneurship within the Biopharmaceutical Technology program. The course carries two credits and comprises 36 contact hours, including 32 hours of theory and 4 hours of practice. It was jointly developed by the college and Qingdao Baheal Pharmaceutical Co, Ltd, supports positions in pharmaceutical preparation and physicochemical drug testing, and includes a practical project on the physicochemical properties and synthesis of aspirin [1]. The course already has a relatively complete knowledge framework organized by drug class, a school–enterprise teaching team, and access to chemical analysis, pharmaceutical analysis, and pharmaceutical simulation laboratories. However, analysis of the alignment among learning outcomes, activities, and assessment evidence reveals several problems excessive content relative to available time, low practice density, insufficiently explicit occupational tasks, limited observability of labor-related professional dispositions, and an underdeveloped evidence chain for learning-outcome attainment.

Against this background, the present study addresses three questions. First, how can disciplinary knowledge in medicinal chemistry be transformed into occupational learning tasks that higher vocational students can understand and complete? Second, how can labor education be embedded throughout structural analysis, laboratory operation, quality judgment, and teamwork? Third, how can outcomes, teaching, and assessment be aligned within 36 contact hours and the existing assessment weighting? The study uses policy and curriculum-text analysis, literature review, occupational-task logic analysis, and curriculum mapping. It is a curriculum-design study; it does not use unverified implementation data or claim effectiveness through fabricated improvements in grades or satisfaction.

Materials and Methods

This study adopted a curriculum-design methodology rather than an intervention-effectiveness design. The principal institutional source was the 2024 Medicinal Chemistry Curriculum Standard for the Biopharmaceutical Technology program at Qingdao Technical College [1]. The document was analyzed for course positioning, contact hours, learning outcomes, module content, practical-training arrangements, school–enterprise participation, assessment weighting, faculty composition, and available training facilities. National vocational-education policies, labor-education policies, pharmaceutical legislation, and the 2025 Chinese Pharmacopoeia were used to establish the regulatory and educational boundary conditions of the reform [2-9].

Relevant literature was retrieved and checked against official government websites, journal platforms, DOI records, or institutional sources. The review focused on integrated theory–practice teaching, medicinal chemistry curriculum and laboratory reform, labor education in higher vocational education, constructive alignment, outcome-based education, active learning, project-based learning, blended learning, and formative feedback [10-22]. Sources that could not be traced to a stable publication record were excluded. Each retained source was used only where its argument or evidence directly supported the corresponding curriculum decision.

The analytical procedure comprised four stages. First, the curriculum standard was diagnosed by comparing intended outcomes, allocated teaching time, learning activities, assessment evidence, and occupational requirements. Second, representative workplace actions were abstracted into occupational task domains, including information retrieval, structural interpretation, property-based judgment, synthesis and impurity analysis, standards interpretation, documentation, and quality communication. Third, constructive alignment was used to map each occupational task to required knowledge, professional work practices, and observable assessment evidence. Fourth, the proposed design was checked against the fixed constraints of 36 contact hours, a four-hour aspirin practical project, and the existing weighting of 50% theoretical assessment, 30% skills assessment, and 20% continuous assessment.

No student grades, questionnaires, interviews, or enterprise-evaluation data were collected for this design study. Consequently, the manuscript reports a traceable reform proposal and implementation logic rather than claims of demonstrated teaching effectiveness. Any subsequent empirical evaluation should obtain appropriate institutional approval and informed consent.

Results/Observations

Current Conditions and Rationale for Reform

A higher vocational course is not an abridged undergraduate course. The distinctive status of vocational education requires learning to be organized around representative occupational tasks, work objects, tools and standards, operating procedures, and quality outcomes [2-4]. In Medicinal Chemistry, vocational distinctiveness does not mean lowering theoretical rigor; it means changing how theory is selected and organized. Concepts that support occupational judgment and subsequent learning should be

retained, while large quantities of fragmented information about individual drugs should be condensed into a reasoning sequence: core scaffold or functional group → physicochemical property → stability or metabolism → quality risk → occupational response. Students need not mechanically memorize every complex systematic name, but they should be able to identify structural indicators of acidity/basicity, hydrolysis, oxidation, photolysis, and related risks, and know when to consult the pharmacopoeia, an approved package insert, or a standard operating procedure (SOP).

Zhang argues that the vehicle for integrating theory and practice in vocational education is the learning-oriented work task, through which theory and practice interact, complement, interpret, and merge with one another as problems, methods, and knowledge are sequenced [10]. This argument directly supports the present reform. Drug structures, properties, structure–activity relationships, and synthetic routes should not be separated from production, testing, storage, and distribution scenarios. Nor should classroom teaching consist of theory followed by a single appended experiment. Instead, students should learn theory while completing a continuous process of reading material information, judging risks, proposing actions, operating or documenting procedures, reviewing results, and improving performance.

Existing studies on medicinal chemistry education provide several useful directions. Dong and Zhou discussed diversified teaching in medicinal chemistry across content, methods, and assessment, emphasizing coordination among values education, cases, discussion, and multiple forms of evaluation [11]. Zhou proposed reforms for laboratory teaching in vocational medicinal chemistry in response to inadequate content and insufficient practical engagement [12]. Zheng et al. explored a laboratory-teaching model that strengthened autonomous learning, experimental planning, and comprehensive competence [22]. More recently, Chen et al. examined teaching innovation in higher vocational Medicinal Chemistry under the "Five Golden" framework and proposed coordinated improvements in theoretical teaching, laboratory teaching, and assessment [14]. Collectively, these studies show that reform has moved beyond improving lectures toward systematic development of theory, experiments, resources, and evaluation.

Three areas nevertheless require further development. First, many studies focus on general undergraduate or pharmaceutical-engineering programs, where objectives emphasize drug discovery and research training; these objectives do not fully correspond to higher vocational roles in pharmaceutical preparation, material inspection, and quality control. Second, projects, cases, and flipped-classroom methods are often presented as parallel techniques without adequately explaining which medicinal chemistry knowledge is required for which occupational task. The result may be methodological accumulation rather than structural curriculum redesign. Third, laboratory reforms frequently emphasize operational ability or learning interest but devote less attention to assessing work behaviors such as contemporaneous raw-data recording, quality verification, deviation reporting, respect for scope of responsibility, and waste disposal. The present study therefore integrates occupational tasks, knowledge and competence, work practice, and assessment evidence within one framework, shifting the focus from "changing methods" to reconstructing the relationships among outcomes, content, activities, and assessment.

International higher-education research on constructive alignment, outcome-based education, active learning, project-based learning, blended learning, and formative feedback offers methodological support for this reconstruction. Biggs emphasized alignment among intended learning outcomes, learning activities, and assessment tasks [15]. Harden et al. advocated backward curriculum design from clear and observable outcomes [16]. Freeman et al. showed the value of discussion, problem solving, and immediate feedback in science courses [17]. Guo et al. noted that project-based learning requires authentic problems, appropriate scaffolding, process feedback, and explicit assessment criteria rather than merely assigning group presentations [18]. Garrison and Kanuka emphasized functional complementarity between online and face-to-face learning, while Nicol and Macfarlane-Dick linked formative feedback to students' self-regulated learning [19,20]. These theories should not be transplanted mechanically, but they help explain why the present course expresses outcomes as observable performances, designs projects around occupational deliverables, and treats assessment as an ongoing feedback process.

Research on labor education also indicates that integration with professional education cannot be achieved through the simple addition of activities. Zhou et al. identified weaknesses in top-level design, professional relevance, practice-base resources, and evaluation systems when vocational labor education is integrated with social practice, and recommended comprehensive practice projects that connect labor education with professional education [21]. Pan, working in the context of higher vocational biopharmaceutical education, analyzed challenges related to educational concepts, resources, faculty, teaching models, and evaluation [13]. These findings closely correspond to the realities of pharmaceutical courses and suggest that labor education must enter professional tasks and assessment standards if the separation between "professional courses teaching knowledge" and "labor courses teaching attitudes" is to be avoided.

The first strength of the current curriculum standard is its clear positioning. The course focuses on relationships between drug structure and pharmacological effect, physicochemical properties, identification methods, and representative synthetic routes, thereby laying a foundation for subsequent courses such as Pharmaceutical Preparation Technology and Pharmaceutical Analysis. Its stated skill points directly support pharmaceutical preparation and physicochemical drug-testing roles [1]. This positioning establishes a boundary for content selection. The primary objective is not to train students to conduct complex new-drug design, but to help them understand material properties, explain quality-related phenomena, identify basic concerns in testing and storage, and develop a structured framework for continued learning.

Second, the curriculum standard already provides a basis for school–enterprise collaboration. It was jointly prepared by college faculty and personnel from Qingdao Baheal Pharmaceutical Co., Ltd. The teaching team includes full-time faculty and an enterprise engineer, and available facilities include chemical analysis, pharmaceutical analysis, and pharmaceutical simulation laboratories [1]. Enterprise participation can therefore progress from "co-writing the standard" to "co-defining task quality." The enterprise can provide de-identified material cards, deviation records, and storage cases; faculty can convert them into teachable tasks; and both parties can evaluate the procedural compliance and occupational usefulness of student deliverables.

Third, the curriculum already emphasizes coordinated ethical and technical development and the integration of professional learning with innovation and entrepreneurship. In addition to

knowledge and skill objectives, the standard stresses that human life and drug quality take precedence, and it highlights engineering ethics, pursuit of excellence, national service through science and technology, and innovation and entrepreneurship. Proposed activities include group learning, pre-class projects, blended learning, and simulation training [1]. The proposed reform therefore does not reject the existing standard. Rather, it translates its value objectives and instructional approaches into explicit tasks, behaviors, and evidence.

The 36-hour course covers antibiotics, anesthetics, psychotropic and neurological drugs, antiallergic and antiulcer drugs, cardiovascular drugs, nonsteroidal anti-inflammatory drugs, antibacterial and antiviral agents, antineoplastic drugs, and drug metabolism. It also addresses the structures, chemical names, properties, applications, structure–activity relationships, mechanisms of action, and selected synthetic methods of numerous representative drugs. A drug-by-drug teaching sequence cannot adequately support structural interpretation, property-based reasoning, occupational application, and classroom interaction at the same time. Students may come to view the course as a test of how many structures they can memorize, while teachers may substitute information coverage for demonstrated attainment.

This contradiction cannot be resolved by simply deleting drug classes. Instead, a hierarchy of "core structural type → representative drug → characteristic property → occupational decision" is required. One or two anchor drugs should be studied in depth within each class, while other drugs should support comparison and transfer. Chemical nomenclature should mainly develop rule-based recognition and information-retrieval skills rather than require rote memorization of every systematic name. Synthetic routes should emphasize the purpose of reactions, key intermediates, potential impurity sources, and safety controls rather than replicate the mechanistic depth of an undergraduate drug-synthesis course. This approach preserves the integrity of the knowledge framework while foregrounding occupational application.

Practical teaching is concentrated in a four-hour investigation of aspirin's physicochemical properties and synthesis. The project benefits from accessible starting materials, a representative reaction, and opportunities for purification and identification, but a single experiment cannot support all skill objectives. If antibiotic stability, acid–base properties and salt forms, photo-oxidative degradation, drug storage, impurity risk, and interpretation of quality standards are taught only through lectures, students have little opportunity to experience how structural information supports workplace judgment. Practice, however, does not necessarily mean adding wet-laboratory experiments. In higher vocational medicinal chemistry, interpreting standards, checking labels, calculating charge quantities, reviewing records, identifying deviations, designing storage conditions, and explaining test phenomena are also forms of professional practice.

A feasible solution is therefore to combine one complete wet-laboratory project with several paper-based or digital micro-tasks and enterprise cases. The aspirin project retains a complete experimental process. Modules on β-lactams, omeprazole, nitrates, antineoplastic drugs, and other topics include 15–30-minute occupational micro-tasks. Simulation platforms can present weighing, charging, reaction, filtration, line clearance, and deviation handling, while pharmacopoeial monographs, package inserts, and safety data sheets can support information-retrieval training. Practice density can thus be increased without substantially increasing equipment demand or contact hours.

The current standard repeatedly emphasizes pursuit of excellence, social responsibility, regulatory compliance, and drug quality and safety. These values are appropriate, but the proposed activities primarily group reports, autonomous learning, and online/offline study do not yet specify the work processes through which students should experience them. "Pursuit of excellence," for example, can be expressed through control of weighing error, repeat measurement, record verification, and investigation of anomalies. "Social responsibility" can be expressed through refusal to conceal or alter nonconforming results and through understanding the risks of antimicrobial misuse and resistance. "Green practice" can be expressed through reduced solvent consumption, segregated waste collection, and evaluation of alternative processes. Without behavioral carriers and assessment requirements, students may learn to use the correct vocabulary in reflections without forming stable habits.

The curriculum standard allocates 50% of the final grade to theoretical assessment, 30% to skills assessment, and 20% to continuous assessment, thereby providing a basic combination of process and summative evaluation [1]. However, a theory examination dominated by structural recall and definitions cannot fully assess structure–property reasoning. A skills examination focused only on the final product cannot reveal procedural compliance, record integrity, or team responsibility. Continuous assessment based mainly on attendance, discipline, and homework likewise offers limited evidence of innovation, reflection, and occupational communication. The overall weighting need not change, but the evidence within each component should be redefined. The theoretical component should include case-based and decision-oriented questions; the skills component should use process observation and analytic rubrics for deliverable quality; and the continuous component should include online preparation, individual task sheets, peer assessment, reflection logs, and records of professional conduct.

The curriculum diagnosis and corresponding reform priorities are summarized in Table 1.

As Table 1 indicates, the central challenge is not to add more chapters, activities, or assessment items, but to address four structural problems: occupational tasks are insufficiently explicit, core knowledge is insufficiently focused, professional work behaviors are difficult to assess, and assessment evidence is inadequately aligned. The subsequent design therefore treats the curriculum standard as its boundary, places drug quality and responsibility for public health at its value core, and reorganizes teaching within the existing 36 hours.

Table 1: Diagnosis of the Curriculum Standard and Priorities for Reform

Diagnostic dimension	Existing foundation	Principal tension	Priority for reform
Course positioning	Professional foundation course integrating theory and practice and supporting innovation/ entrepreneurship; aligned with pharmaceutical preparation and physicochemical testing roles	The disciplinary knowledge system is relatively complete, but occupational work processes are insufficiently visible	Organize structure–property–quality knowledge around representative work tasks
Teaching content	Covers major drug classes, structure–activity relationships, representative syntheses, and metabolism	The number of drugs is excessive for 36 hours and easily creates a memorization burden	Use anchor drugs and a three-level sequence of deep learning, comparison, and transfer
Practical teaching	Includes a four-hour aspirin project and pharmaceutical simulation facilities	One practical project provides insufficient practice density across other modules	Combine a complete experiment, occupational micro-tasks, enterprise cases, and simulation
Labor education	Emphasizes quality responsibility, craftsmanship, regulatory awareness, and innovation	Value statements are prominent, but behavioral indicators and evidence are limited	Translate compliance, integrity, collaboration, safety, green practice, and innovation into task behaviors
Teaching organization	Includes group learning, pre-class projects, and blended learning	Group presentations may become information summaries, and individual contribution is difficult to identify	Use occupational roles, individual task sheets, deliverable standards, and role rotation
Course assessment	Theory 50%, skills 30%, continuous assessment 20%	Assessment content is not sufficiently mapped to course outcomes	Build an evidence chain for knowledge, skills, compliance, and reflection within the existing weighting

Reform Objectives and the Four-Chain Alignment Framework

The overarching objective is that, on completing the course, students will be able to use drug quality and public health as the criteria for professional judgment; apply knowledge of drug structure and properties to basic material identification, stability assessment, storage and handling recommendations, explanation of impurity risks, and communication of quality information; and demonstrate compliance, integrity, collaboration, safety, environmental responsibility, and continuous improvement while performing these tasks. This objective comprises four interrelated dimensions.

At the knowledge level, students should understand major structural classes of drugs, representative functional groups, acid–base behavior, solubility, stability, structure–activity relationships, and basic metabolic reactions. At the competence level, they should be able to interpret structural formulas, chemical names, package inserts, and quality standards; explain experimental phenomena and anomalies; and propose appropriate storage, testing, or disposition recommendations. At the professional-disposition level, they should comply with laboratory and pharmaceutical-work standards, value data integrity and record traceability, and remain alert to drug-quality risks. At the developmental level, they should be able to retrieve information on new drugs, compare drugs within a class, propose preliminary improvements, and build a transferable framework for subsequent study in pharmaceutical preparation, pharmaceutical analysis, and good manufacturing practice (GMP).

To make these outcomes assessable, the curriculum should move beyond stand-alone verbs such as "understand," "be familiar with," and "master," and use an "object + behavior + condition + quality criterion" format. One outcome, for example, may state: "Given the structural formula and quality information of a representative drug, the student can identify key functional groups, explain at least one major stability risk, and propose a storage or retesting recommendation that is supported by standards and remains within the defined scope of responsibility." Another may state: "During the aspirin project, the student can complete weighing, reaction, purification, documentation, and line clearance in accordance with the task brief; report anomalous data truthfully; and explain the results using structural and reaction principles." Such formulations are consistent with outcome-based education and constructive alignment [15,16].

To prevent reform from becoming a collection of unrelated teaching techniques, this study proposes four mutually calibrated curriculum chains. The occupational-task chain consists of obtaining material information, identifying structures, inferring properties, judging risks, performing operations or tests, verifying records, and communicating results. The knowledge–competence chain progresses from functional-group recognition to structural classes, physicochemical properties, structure–activity relationships, synthesis and impurities, metabolism, and safety. The professional work-practice chain comprises preparation, compliant work, collaborative work, work with integrity, green work, and creative work. The assessment-evidence chain includes online quizzes, structure–property reasoning sheets, project worksheets, laboratory records, product samples, oral defense, peer assessment, and reflective reports. The four chains must correspond within every project. Knowledge without an occupational task is easily fragmented; work without scientific knowledge is reduced to procedural training; and professional dispositions without assessment evidence remain rhetorical.

The framework is not four parallel lists. Rather, every project must answer four groups of questions: What occupational task are students simulating? What knowledge and competence are needed to complete it? What professional work qualities should be demonstrated? What evidence will the teacher use to judge attainment? In the β-lactam antibiotic stability task, for example, the occupational task is to review an abnormal storage scenario; the knowledge requirement is to identify the β-lactam ring and explain its susceptibility to hydrolysis; the work-practice requirements are information verification, dual checking, and reporting within the learner's scope of responsibility; and the evidence comprises

individual structural annotation, a team risk-assessment sheet, and a randomly assigned oral defense. Only when all four elements are present can a project avoid degenerating into either a knowledge quiz or a formalistic group activity.

Six principles guide content selection and implementation. First, the curriculum should be "selective in scope, deep in treatment, and transferable in application." It should not attempt to cover every representative drug in each class, but should select anchor drugs that clearly illustrate characteristic structures and quality risks. Second, it should follow "learning through doing, understanding through doing, and reflecting after doing." Practice includes not only laboratory operation but also information retrieval, judgment, documentation, and communication. Third, standards should come first. The pharmacopoeia, drug laws and regulations, package inserts, SOPs, and safety requirements are not optional supplements but the basis for completing tasks. Fourth, student agency and teacher scaffolding should be balanced. Project-based learning does not mean teacher withdrawal; teachers must provide structural-interpretation templates, question sequences, model cases, and timely feedback. Fifth, school and enterprise partners should jointly review content while ensuring that resources remain usable. Enterprise cases should be de-identified, representative, and appropriately difficult rather than copied directly from complex production deviations. Sixth, the process must remain traceable. Individual evidence should accompany group deliverables to prevent free-riding.

The proposed allocation does not mechanically change the 36 contact hours or the four-hour aspirin practical project specified in the curriculum standard. Instead, each module adopts the sequence "deep learning of an anchor drug → comparative analysis of related drugs → transfer to a new drug or situation." Approximately four hours are allocated to foundational concepts and interpretation of standards, 20 hours to structure–property reasoning and representative-drug tasks, eight hours to synthesis, impurities, metabolism, and innovation tasks, and four hours to the complete aspirin practical project. Online preparation addresses drug-development history, basic nomenclature, and structural recognition, while classroom time is prioritized for reasoning, judgment, operation, and feedback. Service-oriented work outside class should neither replace in-class instruction nor be imposed in ways that unnecessarily increase student workload.

College teachers retain primary responsibility for learning outcomes, knowledge structure, learning scaffolds, teaching safety, and grading. Enterprise engineers participate mainly in validating occupational tasks, de-identifying cases, explaining professional standards, and commenting on deliverables. Enterprise cases should satisfy four criteria: authenticity, representativeness, teachability, and compliance. Complex production deviations should not be transferred to students without pedagogical adaptation, and students should never assume responsibility for actual production decisions. School and enterprise partners jointly define the characteristics of a high-quality deliverable—for example, whether a risk-assessment sheet cites structural evidence, whether recommendations follow procedure, whether records are traceable, and whether the wording respects the limits of the learner's authority. In this way, industry–education integration shifts from "an enterprise expert gives one guest lecture" to "the school and enterprise jointly define the quality of course outcomes."

Occupationally Oriented Content Reconstruction and Project-Based Implementation

The original curriculum modules can remain as a knowledge index, but classroom organization need not follow the textbook chapter by chapter. The content can be reorganized into five cross-module task domains. The first is structural interpretation and information retrieval, in which students learn to identify core scaffolds, functional groups, stereocenters, salt forms, and nomenclature cues and use the pharmacopoeia, package inserts, and reliable databases to verify drug information. The second is physicochemical properties and storage/handling decisions, in which acidity/basicity, solubility, hydrolysis, oxidation, photolysis, and thermal stability are used to explain packaging, storage, compatibility, and dosage-form selection. The third is synthetic routes and impurity risks, in which students examine the purpose of key reactions, risks associated with starting materials and intermediates, and possible side products, residues, and degradation impurities. The fourth is quality standards and testing decisions, in which students interpret descriptions, identification tests, related-substance requirements, assay items, and storage conditions and decide what should be tested and how an anomaly should be handled. The fifth is innovative design and professional ethics, in which comparison within drug classes, histories of structural modification, new-drug development cases, and drug-quality incidents are used to develop innovation and responsible judgment.

These task domains do not reject the original knowledge system; they make explicit why the content is learned and how it is used at work. A β-lactam antibiotic module can simultaneously support structural interpretation, stability judgment, and impurity-risk analysis. The aspirin module can support synthesis, purification, identification, documentation, and green-process improvement. An antineoplastic-drug module can foreground occupational protection, risk communication, and ethical responsibility. A drug-metabolism module can explain structural modification, metabolic soft spots, and safety. Repeated use of core concepts across modules helps students form a stable structure–property analysis framework.

The mapping from the original modules to occupational tasks is presented in Table 2.

Table 2 retains the original modules as a knowledge index, but each module specifies a work object, an occupational deliverable, and expected work behaviors. Students are no longer asked merely, "How many drugs must I memorize in this chapter?" Instead, they are asked, "What judgment must I make about this drug, why is that judgment justified, and what reviewable evidence must I leave behind?"

Table 2: Mapping the Original Curriculum Modules to Occupational Tasks

Original module	Anchor drug/topic	Occupational task	Labor-education emphasis	Primary evidence
Foundations of medicinal chemistry	Drug-quality standards and structural information	Interpret pharmacopoeial monographs/package inserts and verify structure, name, storage, and quality items	Standards awareness, honest retrieval, responsibility for information	Standards-interpretation sheet; source list
Antibiotics	Amoxicillin; cefalexin	Analyze β-lactam stability and propose storage and testing priorities	Sensitivity to quality risk, compliant verification, responsibility for rational use	Structure–risk diagram; storage recommendation
Anesthetics and psychotropic drugs	Procaine; lidocaine; diazepam	Compare structures, salt forms, and metabolism and identify special-control and safety risks	Legal compliance, professional boundaries, safety awareness	Comparison table; risk-communication card
Antiallergic and antiulcer drugs	Diphenhydramine; omeprazole	Use acid–base behavior and stability to judge dosage-form and storage conditions	Careful observation and evidence-based decision making	Scenario judgment; disposition note
Cardiovascular drugs	Glyceryl trinitrate; nifedipine; captopril	Identify light, heat, and oxidation risks and review a material-storage plan	Safe work, dual verification, responsible communication	Risk checklist; review opinion
Nonsteroidal anti-inflammatory drugs	Aspirin	Complete synthesis, purification, identification, documentation, waste segregation, and quality evaluation	Compliant operation, data integrity, green work, continuous improvement	Laboratory record; sample; quality report
Antibacterial and antiviral drugs	Sulfamethoxazole; ciprofloxacin; acyclovir	Compare structure–activity relationships and explain responsible use and resistance risk	Social responsibility, scientific medication use, public-health awareness	Public-information product; structural comparison
Antineoplastic drugs	Cyclophosphamide; fluorouracil; cisplatin	Identify cytotoxicity and occupational-exposure risks and specify protection and waste-disposal requirements	Bioethics, protection responsibility, hazardous-waste management	Occupational-protection card; emergency procedure
Drug structure and metabolism	Oxidation, hydrolysis, and conjugation	Locate metabolic soft spots and degradation sites and explain structural-modification strategies	Scientific integrity, innovation, and risk anticipation	Metabolic-pathway sketch; improvement proposal

A three-tier content structure can address the shortage of contact hours. Core-required content includes the defining structural features, critical properties, quality risks, and occupational applications of representative drugs and should be attained by all students. Proficiency content includes comparisons within a class, representative structure–activity relationships, and simple synthetic routes and can be learned mainly through group tasks and case analysis. Extension content includes new-drug developments, complex nomenclature, detailed metabolic pathways, and innovative design and can be selected by students with stronger foundations, skills-competition teams, and innovation or entrepreneurship projects. Tiering does not lower standards; it prioritizes high-value content that supports occupational competence within limited time.

In the antibiotic module, for example, amoxicillin and cefalexin can serve as core anchor drugs. Students should identify the β-lactam ring, amino and carboxyl groups, and other relevant structural elements and use them to explain susceptibility to hydrolysis, acid–base behavior, and storage requirements. Piperacillin and ceftazidime can be used to compare how structural modifications influence spectrum or stability. General semisynthetic routes and mechanisms of resistance can be treated as proficiency or extension content. In the cardiovascular module, glyceryl trinitrate, nifedipine, and captopril can represent different types of risk, including volatility/explosion and adsorption, photosensitivity, thiol oxidation, and impurity control.

The 2025 edition of the Pharmacopoeia of the People's Republic of China, effective October 1, 2025, is an important technical basis for quality control in drug research, production, distribution, and use [9]. Students should therefore understand that medicinal chemistry is not theory detached from standards; it provides the scientific basis for understanding why particular test items and limits are specified. Teachers can select publicly accessible monographs or standardized excerpts and ask students to annotate items such as description, identification, related substances, assay, and storage. Follow-up questions may include: Why must the material be protected from light, tightly closed, or refrigerated? Why is a particular degradation product controlled as a related substance? Which structural region is likely to change? Such questions integrate structural knowledge, pharmacopoeial literacy, and quality responsibility.

The Drug Administration Law emphasizes whole-process quality management in drug research, production, distribution, and use

to protect medication safety and the lawful rights and interests of the public [8]. Classroom micro-scenarios can ask whether an unexpected experimental result may be deleted, whether a missing entry in a partner's record may be back-signed, or whether a sample with a blurred label but normal appearance may continue to be used. Students must make decisions based on law, laboratory rules, and quality principles and explain the possible consequences. Labor education thus becomes part of professional judgment rather than abstract moral instruction.

A three-step method "locate the requirement → explain it structurally → translate it into occupational action" can guide interpretation of standards. Students first locate information concerning description, identification, related substances, assay, and storage. They then explain the rationale using functional groups and reaction properties. Finally, they translate the information into a material label, storage recommendation, or testing priority. In this way, the pharmacopoeia and relevant legislation become working references rather than supplementary content presented at the end of the course [8,9].

The aspirin project, explicitly specified as a four-hour practical component in the curriculum standard, should be upgraded from "verifying a reaction" to "completing a traceable small-scale production and quality task." Before class, students study acetylation, aspirin hydrolysis, and safety information for starting materials and products, then complete risk identification and charge calculations. At the beginning of the practical session, each group receives a task brief specifying product requirements, allowable deviations, record formats, and waste-disposal requirements. Roles such as material controller, operator, recorder, and quality verifier are assigned and rotated in subsequent stages so that every student assumes an identifiable responsibility.

During the experiment, the teacher should assess more than whether crystals are obtained. Key observations include weighing, labeling, time recording, temperature control, filtration and washing, sample numbering, anomaly reporting, and line clearance. Product evaluation may include appearance, melting point or an appropriate identification reaction, yield calculation, and impurity-risk analysis. Students should explain whether damp product, a depressed melting range, or a positive salicylic-acid reaction is likely to result from a particular operation or from degradation. An unsatisfactory result is not necessarily a failed project. If records are authentic, analysis is reasonable, and feasible improvement measures are proposed, process credit should still be awarded. This approach discourages selective documentation merely to produce a visually "successful" outcome.

Labor education must be made concrete within the project. Compliant work is demonstrated through appropriate personal protective equipment, SOP-based weighing, and line clearance. Work with integrity is demonstrated through contemporaneous raw records, no unmarked alteration, and no deletion of anomalous data. Collaborative work is demonstrated through role allocation, dual verification, and handover confirmation. Green work is demonstrated through microscale operation, avoidance of unnecessary washing, and separate collection of acidic and organic waste. Creative work is demonstrated through reasoned consideration of improvements to catalyst loading, crystallization conditions, or solvent selection. At the end of the project, students submit a one-page quality review addressing whether requirements were met, what the most critical risk was, and what they would change next time.

The task sequence and assessment evidence for the aspirin project are detailed in Table 3.

The project draws on previous laboratory-teaching reforms that emphasize student planning, process training, and comprehensive competence [12,22]. but it extends evaluation to record integrity, occupational verification, anomaly reporting, and green disposal. Obtaining white crystals is not treated as the sole criterion for success. The project is judged comprehensively according to procedural compliance, completeness of evidence, scientific quality of causal analysis, and feasibility of improvement recommendations.

Table 3: Task Sequence and Assessment Evidence for the Aspirin Project

Stage	Student task	Teacher scaffold	Observed professional disposition	Assessment evidence
Pre-class preparation	Retrieve structural, physicochemical, and safety information; calculate charge quantities; identify risks	Resource list, calculation template, and risk examples	Active preparation, information integrity, safety awareness	Online quiz; preparation sheet
Task initiation	Read the work order; confirm roles, product requirements, and allowable deviations	Clarify task boundaries and model documentation requirements	Responsibility allocation, communication, and handover	Role card; task-confirmation form
Experimental implementation	Weigh, react, crystallize, filter, wash, and label samples	Monitor critical points and question anomalies	Compliant operation, dual verification, conservation of materials	Process-observation form; raw record
Quality evaluation	Observe appearance, complete identification/ testing, calculate yield, and analyze anomalies	Provide standards and a structured judgment sequence	Data integrity, evidence awareness, risk judgment	Sample; test record; quality report
Line clearance and disposal	Clean apparatus, return materials, segregate waste, and clear the work area	Inspect line clearance and waste handling	Safe work, green work, public responsibility	Line-clearance checklist
Review and improvement	Explain deviations, individual contribution, and an improvement plan	Organize peer review and teacher feedback	Reflection, respect for others' work, continuous improvement	Reflection log; peer assessment

This micro-project uses a material card for amoxicillin or cefalexin and can be completed without conducting an actual degradation experiment. The teacher provides a structural formula, a simplified package insert a simulated storage record, and two descriptions of material condition that differ in important details. Students first identify the β-lactam ring, amino group, carboxyl group, and other critical features and infer hydrolytic susceptibility and acid–base behavior. They then analyze the quality risks associated with scenarios such as loss of package integrity, elevated environmental humidity, or excessive holding time in solution. Finally, they propose recommendations for storage, sampling, retesting, or quarantine.

The deliverable is not a generic group slide deck but an occupational risk-assessment sheet containing structural evidence, risk level, additional information required, recommended actions, and verification signatures. Assessment focuses on the completeness of the reasoning chain, whether recommendations exceed the students defined authority, and whether uncertainty is made explicit. Students may recommend quarantine pending testing or additional related-substance analysis, for example, but they should not declare a material rejected when the evidence is insufficient. Such boundary education helps students understand that technical personnel must be willing to identify problems while communicating and acting through established procedures.

The micro-project can be completed within one class hour and produces three forms of evidence: individual structural annotation, group risk assessment, and randomly assigned occupational oral defense. By asking, "What additional information would be required before reaching a conclusion?" and "Does this recommendation exceed your scope of responsibility?" the teacher develops evidence-based thinking and professional boundaries, preventing students from assuming that structural reasoning alone permits a final quality disposition.

The structure and acid instability of omeprazole provide an effective context for explaining how drug properties influence dosage-form design. The teacher can present three scenarios: release from a conventional tablet in the stomach, damage to the coating of an enteric-coated preparation, and exposure of the active pharmaceutical ingredient to an inappropriate acid–base environment. Students use structural information and previously learned properties to predict possible changes, explain the need for enteric protection, and review a storage card containing requirements such as protection from light, tight closure, and dry conditions. This project can connect Medicinal Chemistry with Pharmaceutical Preparation Technology and help students see that medicinal chemistry is not an isolated prerequisite but a basis for understanding formulation and process choices.

The classroom sequence can follow "individual judgment → group argumentation → whole-class questioning → teacher synthesis." Individual judgment ensures that every student thinks before discussion; group argumentation develops evidence-based communication; whole-class questioning exposes misconceptions; and the teacher then generalizes the conclusions into broader principles concerning acid–base behavior, stability, and formulation protection. Assessment combines brief written responses, structural annotation, and oral explanation rather than judging only the final answer.

The project also supports continuity across the program. In Medicinal Chemistry, students learn why acid instability and structural risk matter. In a subsequent course on pharmaceutical preparation, they study enteric materials, formulation, and process control in greater depth. The project deliverable can be retained as a prerequisite-learning artifact for the later course, reducing fragmentation across the curriculum and strengthening continuity within the professional program.

A comparative review task can use glyceryl trinitrate, nifedipine, and captopril to ask whether one storage scheme is suitable for all three materials. Students identify the safety risk associated with the nitrate ester, the photosensitivity of nifedipine, and the oxidation risk associated with captopril's thiol group, and then propose differentiated requirements for segregation, packaging, protection from light, tight closure, or retesting. The task emphasizes that professional work is not the mechanical application of one uniform procedure but the differentiated control of materials according to their properties.

Group roles may include warehouse personnel, quality personnel, production personnel, and safety personnel. Each role presents concerns derived from its responsibilities, and the group produces a unified review conclusion. Structured role conflict helps students understand trade-offs among quality, efficiency, and safety, while reinforcing that no efficiency improvement may breach regulatory or quality limits.

An antibacterial or antibiotic module can also include a small science-communication service project for the campus or local community. Students select a commonly used antibacterial drug and prepare structured public information that does not provide diagnosis or individualized treatment advice and does not overstate efficacy. The material explains the drug class, general indications, why self-directed misuse should be avoided, storage precautions, and when professional assistance should be sought. The medicinal chemistry teacher and a pharmacy-related colleague jointly review scientific accuracy and professional boundaries. The task connects service-oriented work with professional learning and shows students that drug knowledge is not merely examination content but can contribute to public health.

Service-oriented work must not cross professional boundaries. Students may not present themselves as pharmacists, provide individualized prescription advice, or circulate unverified adverse-effect claims or online information. Assessment should address reliability of sources, accuracy of language, completeness of risk communication, and service attitude. Feedback from authentic audiences can help students reflect on how professional language should be translated into information the public can understand.

Scientific accuracy and scope of responsibility are therefore essential. Students may provide general education on drug storage or responsible antibiotic use, but they may not diagnose individuals, recommend prescriptions, or promise treatment outcomes. All materials must be reviewed by a teacher before dissemination. Drawing on the recommendation to develop comprehensive practice projects that integrate labor education and professional education [21], the course structures science communication as a professional workflow of "information verification → audience-oriented translation → risk communication → feedback-based revision," rather than as an undifferentiated volunteer activity.

Pre-class resources should be concise, explicit, and directly connected to the classroom task. Each module may provide a 5–10-minute microlecture, representative-drug structure cards, a terminology list, an excerpt from a pharmacopoeial monograph or package insert, and three to five diagnostic questions. Students

should submit more than evidence that they watched a video; they should submit structural annotations, critical questions, and points of uncertainty. The teacher uses platform data and student questions to adjust classroom priorities. Students with weaker foundations can receive remedial resources on functional groups, acid–base judgment, and basic organic reactions, while more advanced students can receive materials for within-class comparison or new-drug extension.

Pre-class workload must be controlled. Requiring lengthy information searches for every module merely transfers teachers' preparation burden to students and encourages copying from the internet. Effective preparation should normally be completed within 20–30 minutes and feed directly into classroom discussion. Source hierarchies should be specified: the pharmacopoeia, national drug-regulatory authorities, textbooks, approved package inserts, and scholarly databases should take precedence over short videos or commercial websites.

Classroom teaching begins with a contextualized problem rather than a list of facts. In a β-lactam lesson, for example, the teacher may present a simplified case in which retesting of one batch produces an abnormal result after storage under high humidity. Students are asked which structural region should be examined first, what change may have occurred, and which quality items should be consulted. The teacher then develops the relevant structural characteristics, hydrolysis mechanism, and stability considerations from the students' responses. Knowledge is introduced in response to a problem, making its purpose more visible.

Each core concept should pass through four stages: identification, explanation, comparison, and transfer. Identification means locating a functional group or core scaffold. Explanation means describing its effect on properties. Comparison means analyzing structural differences among related drugs. Transfer means solving a new storage, testing, or compatibility problem. Rotatable molecular models, layered color coding of structures, and reaction animations can support teaching, but visualization must serve reasoning rather than replace students' own drawing, annotation, and explanation.

Post-class tasks should require transfer to a new context instead of reproducing class notes. After studying aspirin, students may compare the structure and major properties of paracetamol. After studying omeprazole, they may analyze the shared structural features of another proton-pump inhibitor. After studying captopril, they may identify storage requirements for another drug containing an oxidation-prone group. A common template "structural evidence → property judgment → occupational recommendation → information source" helps students develop a transferable analysis framework.

Reflection is an important stage in the internalization of labor education. After each project, students briefly answer: What professional work did I undertake? Which behavior most affected quality? Did I record anomalies truthfully? Did I respect the work of other group members? What will I improve next time? Teachers should assess concrete events, causal analysis, and feasibility of improvement rather than rhetorical sophistication.

Unequal contribution is a common problem in group-based vocational projects. Groups of four or five students, rotating occupational roles, and deliverables that contain both a shared and an individual component are recommended. The shared component may be a risk-assessment sheet or quality report; the individual component may be a structure–property reasoning question, oral defense, occupational log, or random questioning. Peer assessment should carry only modest weight and require factual evidence. Teachers should retain the authority to adjust within-group score differences to protect fairness.

The functional division in blended teaching is "online for foundational input, face-to-face for higher-order interaction, and post-class work for transfer to a new context." Online resources should not be judged by quantity, and face-to-face lessons should not repeat microlectures. Instead, classroom problem sequences, peer argumentation, and immediate feedback should respond to diagnostic results, consistent with the integrative principles of blended learning [19]. Project-based learning should be anchored in a clearly defined work object, a deliverable, process scaffolding, and individual accountability so that a group presentation does not substitute for learning [18].

The core of professional work in pharmaceutical settings is respect for life, standards, facts, and collaboration. Drug quality cannot be "tested into" a finished product; it is generated through every act of weighing, charging, operating, documenting, verifying, and clearing the work area. Although Medicinal Chemistry is not a GMP operations course, structural and physicochemical knowledge can help students understand the scientific reasons behind required practices: tight closure controls moisture or volatilization; protection from light limits photodegradation; low temperature reduces reaction rates; and dual verification reduces error risk. When students understand why a practice is required, compliance is less likely to become mechanical obedience.

Six categories of professional work behavior are proposed. First, compliant work means following the task brief, safety requirements, and operating procedures and using personal protective equipment, labels, and apparatus correctly. Second, work with integrity means recording raw data promptly, authentically, and completely; not selectively deleting data; and not concealing mistakes. Third, collaborative work means clarifying roles, communicating proactively, respecting others' contributions, and completing handovers and verification. Fourth, safe work means identifying risks associated with chemicals, equipment, and occupational exposure and being able to stop and report unsafe operations. Fifth, green work means conserving reagents and consumables, segregating waste correctly, and understanding green synthesis and process optimization. Sixth, creative work means proposing improvements to processes, resources, or communication without breaching quality and safety limits. These six categories can be used throughout project observation and student self-reflection.

Education about professional dedication should not be separated from disciplinary content. When enterprise engineers or exemplary skilled workers participate in class, their contributions should focus on concrete quality situations: how an anomalous result was investigated, why a complete record mattered, what consequences followed from inadequate line clearance, or how a process improvement emerged through repeated trials. The teacher then converts the account into a task and assessment standard so that role-model education becomes behavior students can emulate.

A lightweight school–enterprise mechanism can follow the sequence "enterprise proposes the problem → teacher adapts it for learning → students complete the task → both parties evaluate the outcome." The enterprise provides de-identified problems and occupational requirements; the teacher controls conceptual difficulty and designs scaffolds; and the enterprise teacher comments on procedural compliance and usability. Because

the curriculum standard already provides a basis for enterprise participation and adjunct teaching, the reform should prioritize fit between cases and learning outcomes rather than the number of enterprise cases.

Students in higher vocational pharmaceutical programs may use their learning to provide public education on drug storage, responsible medication use, and antimicrobial resistance, but professional boundaries must remain explicit. Teachers should review all service materials, which must not involve individual diagnosis or medication adjustment. When members of the public ask personal questions, students should learn to say, "This requires assessment by a licensed pharmacist or physician." Recognizing the limit of one's role is itself a form of professional ethics. Audience feedback on clarity and usefulness can then help students improve professional communication.

The six categories of professional work disposition are not assessed through a separate form unrelated to disciplinary learning. They are embedded at critical points in each project. Compliance is evidenced by safety preparation, labeling, and SOP execution; integrity by raw records, anomalous data, and information sources; collaboration by role handover, dual verification, and evidence-based peer evaluation; green work by reagent conservation, waste segregation, and line clearance; and creativity by improvement proposals that remain within quality limits. Pan identified practical barriers involving resources, faculty, models, and evaluation when labor education is integrated with professional education [13]. The present curriculum therefore uses "small tasks, strong evidence, and repeatable routines" to reduce implementation cost.

Diversified Assessment and Implementation Support

Because the curriculum standard already specifies 50% theoretical assessment, 30% skills assessment, and 20% continuous assessment, the internal structure can be redesigned without changing the overall weighting. Within the 50% theoretical component, basic recall should account for approximately 40%, while structure–property explanation, comparison, and case-based decision making should account for approximately 60%. The 30% skills component should be centered on the complete aspirin project and supplemented by simulation operations, interpretation of standards, and risk judgment. The 20% continuous component should include pre-class diagnostics, individual classroom tasks, project collaboration, reflection, and compliant performance rather than relying mainly on attendance and the number of assignments submitted.

The proposed assessment scheme and its principal rubric dimensions are shown in Table 4.

This redesign does not alter the percentages prescribed by the curriculum standard; it increases the explanatory value of each component. The theoretical score indicates whether students understand and can transfer structure–property knowledge. The skills score indicates whether they can operate compliantly and leave appropriate evidence in authentic or simulated tasks. The continuous-assessment score indicates whether they prepare consistently, think independently, assume defined roles, and reflect on improvement. Together, the three components provide evidence of learning-outcome attainment and cannot substitute for one another.

Table 4: Proposed Assessment Scheme and Key Rubric Dimensions

Assessment component	Weight	Primary tasks	Core dimensions	Aligned learning outcomes
Theoretical assessment	50%	Structural recognition, property explanation, structure–activity comparison, and case-based decisions	Accuracy, completeness of reasoning, use of standards, and transfer	Foundational knowledge; structure–property analysis; quality judgment
Skills assessment	30%	Aspirin project, simulation operations, standards interpretation, and risk analysis	Safety, compliance, documentation, results, anomaly analysis, line clearance, and collaboration	Laboratory skills; compliant work; problem solving
Continuous assessment	20%	Online diagnostics, individual task sheets, classroom participation, reflection, and project contribution	Preparation, independent thinking, information integrity, responsibility, and continuous improvement	Self-directed learning; collaboration and communication; professional work disposition; innovation

The theoretical examination must still assess foundational knowledge, but questions should shift from "write the complete chemical name of a drug" to "use structural information to answer an occupational question." A structure containing a β-lactam ring may be provided, and students asked to identify the reactive region, judge unsuitable environmental conditions, and explain the reasoning. Aspirin and salicylic acid structures may be presented, and students asked to explain their degradation relationship and propose an identification approach. An omeprazole storage scenario may be given, and students asked to identify risks and cite evidence. Chemical nomenclature can be assessed through matching structures with names and recognizing critical naming fragments rather than using memorization of complex names as the principal discriminator of achievement.

Skills assessment should use an analytic rubric with at least seven dimensions: preparation and safety, procedural compliance, documentation and traceability, quality of results, analysis of anomalies, line clearance and waste disposal, and teamwork. Product quality should not dominate the rubric; otherwise, students may neglect compliance in pursuit of a high yield. Students who make an operational error but stop promptly, report it honestly, analyze it reasonably, and propose an improvement should receive appropriate process credit. Conversely, a superficially successful result accompanied by back-filled records, contradictory data, or breach of a safety limit should incur explicit penalties and may be judged unsatisfactory for that criterion.

Professional work dispositions should not be assessed only through self-report. Four evidence sources can be combined: teacher observation, factual peer assessment, individual reflection, and deliverable review. Teacher observation records whether students prepare on time, assume a role actively, perform verification, and dispose of waste correctly. Peer assessment must identify specific

contributions or problems. Individual reflection explains an event and an improvement. Deliverable review examines record completeness, data consistency, and signature traceability. No single source should carry excessive weight; the principal purpose is feedback and improvement.

At the end of the course, an attainment matrix can be established for each learning outcome. Outcome 1, "identify structures and explain properties," may be supported by online quizzes, the theoretical examination, and structure–property reasoning sheets. Outcome 2, "address stability and testing problems," may be supported by case questions, occupational micro-projects, and project reports. Outcome 3, "complete experiments and documentation compliantly," may be supported by the skills rubric and laboratory records. Outcome 4, "demonstrate quality responsibility and labor-related professional dispositions," may be supported by process observation, reflection, and records of integrity-related incidents. Outcome 5, "collaborate and innovate," may be supported by role rotation, peer assessment, and improvement proposals. If evidence for an outcome is overly narrow or attainment is low, the next teaching cycle should adjust tasks, scaffolding, or time allocation rather than simply requiring students to study longer.

Formative assessment should run through the entire project process. The teacher adjusts problem difficulty after pre-class diagnosis, gives immediate feedback on conceptual misconceptions during classroom reasoning, marks traceability problems in project records, and requires students to identify a next action during review. Feedback should specify current performance, the target standard, and a route for improvement rather than merely provide a score, consistent with the role of formative feedback in self-regulated learning [20].

The course team should establish an "outcome → assessment task → scoring criterion → evidence source" matrix and regularly examine whether an outcome is supported by only one examination item, whether the same evidence is counted repeatedly, whether professional dispositions rely solely on self-assessment, or whether group scores conceal individual differences. Versions of theory papers, project rubrics, laboratory records, and reflection logs should be retained. Enterprise teachers can blindly sample de-identified student deliverables, while college teachers compare rating differences and revise rubrics accordingly. Active learning and project-based learning do not automatically produce better outcomes; the quality of assessment and feedback determines whether they are effective [17,18].

Assessment must also include non-negotiable quality and safety thresholds. Fabricating data, signing another student's record, concealing a major safety issue, or deliberately mixing samples or waste should not be fully offset by high scores elsewhere. Students whose results are unsatisfactory but whose records are authentic, reporting is timely, and causal explanation is sound should retain reasonable process credit. These rules communicate a central principle of pharmaceutical work: authenticity, compliance, and traceability come before an attractive result, and quality integrity cannot be traded for performance.

Four resource packages are recommended. A structural-learning package includes representative-drug structure cards, functional-group maps, structure–property reasoning templates, and molecular models. An occupational-standards package includes public excerpts from pharmacopoeial monographs, package inserts, safety data sheets, simulated SOPs, material cards, and test records. A project-implementation package includes task briefs, worksheets, role cards, rubrics, anomaly cases, and model answers. A digital package includes microlectures, animations, simulations, an online item bank, and a learning-data dashboard. Resource names, versions, and source dates should be standardized, and resources should be revised promptly when the pharmacopoeia or relevant regulations change so that students do not use outdated information.

College teachers are responsible for learning outcomes, knowledge structure, scaffolding, and process assessment, while enterprise teachers are responsible for occupational standards, case authenticity, professional boundaries, and the usability of deliverables. Enterprise teachers need not participate in every chapter. Their contribution can focus on project validation, representative cases, end-of-course review of student work, and faculty practice development. Early-career teachers can use enterprise placements to learn about material management, deviation investigation, quality testing, and documentation requirements. Experienced teachers can then convert complex workplace experience into tasks that are appropriate for higher vocational students.

The curriculum standard identifies chemical analysis, pharmaceutical analysis, and pharmaceutical simulation laboratories. These facilities can be used in a tiered manner. High-risk processes or procedures that exceed available course time can be completed in the simulation laboratory; structure–property work and basic identification can be completed in the chemical analysis laboratory; and demonstrations or visits related to understanding quality-test items can take place in the pharmaceutical analysis laboratory. Safety induction and operational demonstration are mandatory before practical training. Records of equipment, consumables, waste, and anomalies should be retained after training to support continuous course improvement.

A textbook suitable for higher vocational students can continue to provide the main knowledge sequence, but the textbook table of contents should not be treated as the curriculum structure. Teachers should update cases according to the 2025 Chinese Pharmacopoeia, current drug legislation, professional teaching standards for vocational education, and relevant technical developments. New-drug developments should be selected because they illuminate a core concept—for example, a new β-lactamase inhibitor can illustrate structural modification in response to resistance—rather than because they are fashionable. All online resources should identify their source and access date, thereby modeling traceable information use.

Resource construction should include source and version control. Legislation, pharmacopoeial monographs, package inserts, and SOP excerpts should carry publication or access dates. Enterprise cases should state the extent of de-identification and pedagogical adaptation. Structure cards, task briefs, rubrics, and model answers should use a unified numbering system. This approach supports course-team iteration and models professional information traceability for students. The "Five Golden" study on teaching innovation in higher vocational medicinal chemistry emphasizes coordinated development of course content, laboratory teaching, and assessment [14]. The present proposal extends that coordination by incorporating enterprise-defined deliverable quality and evidence of professional work behavior.

Discussion

Educational Contributions and Implementation Logic

The reform contributes to higher vocational medicinal chemistry in

three respects. First, it treats occupational relevance as a change in the organization and use of knowledge rather than as a reduction in theoretical rigor. Structural and physicochemical concepts remain central, but they are repeatedly mobilized in storage, testing, synthesis, impurity, documentation, and risk-communication tasks. Second, it translates labor education into observable professional work practices compliance, integrity, collaboration, safety, green work, and responsible innovation rather than leaving it as general moral exhortation. Third, it preserves institutional constraints while changing the quality of learning evidence, thereby offering a feasible route for courses with limited contact hours.

The four-chain framework also clarifies the division of responsibility in school–enterprise collaboration. Enterprise participation is most valuable when occupational standards, case authenticity, and deliverable quality are jointly defined, whereas the college retains responsibility for curricular coherence, student safety, scaffolding, and grading. This boundary prevents authentic cases from becoming either unadapted workplace complexity or symbolic guest lectures. At the same time, the framework makes individual evidence indispensable within group projects, reducing the risk that presentation quality or a single final product conceals uneven learning.

Continuous Improvement and Subsequent Empirical Evaluation
In the Plan phase, occupational requirements and attainment data from the previous cycle are used to select anchor drugs, project difficulty, and assessment priorities. In the Do phase, the course team records online learning, classroom performance, project results, and common errors. In the Check phase, the team analyzes evidence for each learning outcome, student reflections, and enterprise-teacher feedback. In the Act phase, it revises task instructions, resources, time allocation, and rubrics. Each cycle should produce a concise course-quality report documenting what was changed, the evidence for the change, and how the next cycle will test it. This prevents reform from remaining dependent on individual experience and enables cumulative improvement.

Five implementation questions deserve continued monitoring. First, is the content load reasonable? Evidence may include completion of pre-class work, patterns of classroom error, and students' time investment. Second, do projects genuinely promote transfer from structure to property? This should be tested with new-context questions rather than repeated versions of the original task. Third, does labor education produce observable behavioral change? Indicators may include timeliness of documentation, verification habits, anomaly reporting, and waste disposal. Fourth, is group collaboration fair? Individual tasks, random oral defense, and peer evidence can be compared. Fifth, are enterprise cases appropriate? Student comprehension and enterprise-teacher judgment should be considered together.

The present study proposes a reform design and does not yet use longitudinal data from multiple cohorts to establish effectiveness. Subsequent work may adopt action research or a quasi-experimental design. Adjacent cohorts before and after reform can be compared, provided that entry-level preparation, teacher assignment, and examination difficulty are reasonably comparable. Outcomes may include performance on novel structure–property transfer questions, project-rubric scores, attainment of course outcomes, and learning engagement. Interviews or open-ended questionnaires can explore students' perceptions of occupational relevance, task difficulty, and professional work dispositions. Enterprise teachers can blindly review a sample of deliverables for procedural compliance and occupational usefulness. Reports should present both positive and unmet outcomes rather than relying solely on satisfaction or final average grades.

If teaching research collects student questionnaires, grades, work products, or interview data, the project should obtain the relevant institutional approval and informed consent, clarify data use, ensure anonymization, and protect the right to withdraw. Participation in research should be appropriately separated from course grading so that students do not feel compelled to participate because of concern about their grades. Research data and scoring rubrics should retain version histories to ensure traceability. These research practices themselves model honest work and scientific ethics.

Implementation may proceed through two consecutive action-research cycles. The first cycle can focus on task difficulty, classroom timing, and rubric usability. The second can adjust anchor drugs and scaffolds in response to error patterns and attainment evidence. Any before–after comparison should control, as far as practicable, for teacher, student preparation, and item difficulty and should prioritize novel transfer questions, project rubrics, and blinded enterprise assessment over final mean scores or satisfaction alone. The present manuscript provides a design grounded in the curriculum standard and traceable literature; its educational effects still require evaluation with authentic data.

Scope Limitations and Transferability
The proposal is intended for higher vocational Medicinal Chemistry courses with limited contact hours and a primary role as a professional foundation supporting occupational competence. Institutions with more laboratory hours may add comparative stability studies, purity testing, or small-scale synthesis optimization. Programs oriented more strongly toward biopharmaceutical production may reduce detailed treatment of complex traditional small-molecule synthesis and increase comparisons of quality attributes between small-molecule drugs and biologics. Students preparing for articulation into bachelor-level study may complete extension work in nomenclature, reaction mechanisms, and structure–activity relationships. Regardless of local adaptation, occupational demand, student preparation, available time, and continuity with subsequent courses must remain balanced.

The principal limitation is that the manuscript presents a curriculum-design model rather than evidence from a completed intervention. Its feasibility and effects therefore require prospective evaluation with authentic course data, including novel transfer tasks, process-rubric scores, learning-outcome attainment, implementation workload, and blinded review of selected student deliverables. The design is institutionally grounded and may require adaptation to different contact hours, student preparation, laboratory conditions, and regulatory environments.

Conclusion
The Medicinal Chemistry curriculum standard for the Biopharmaceutical Technology program at Qingdao Technical College already provides a relatively complete drug-class knowledge system, explicitly supports roles in pharmaceutical preparation and physicochemical drug testing, and offers a foundation in school–enterprise collaboration, project learning, values education across the curriculum, and simulation training [1]. The proposed reform does not merely rename the course or compress its contents. It reconstructs learning outcomes, content, and implementation in response to structural discontinuities among knowledge coverage, occupational application, labor education, and assessment evidence.

The four-chain alignment framework uses the occupational-task chain to determine the contexts in which knowledge is applied, the knowledge–competence chain to ensure that occupational judgment has a scientific basis, the professional work-practice chain to translate compliance, integrity, collaboration, safety, environmental responsibility, and innovation into observable behavior, and the assessment-evidence chain to determine whether course outcomes have actually been attained. Five occupational task domains, one complete aspirin project, and several micro-projects increase practice density while retaining drug-class modules as a knowledge index. This avoids interpreting vocational distinctiveness as a weakening of theory.

The reform retains the institutional weighting of 50% theory, 30% skills, and 20% continuous assessment, but reconstructs the internal evidence through case-based questions, process rubrics, individual task sheets, project records, random oral defense, and reflection logs. Knowledge, skills, and professional work dispositions are therefore evaluated as connected components. School–enterprise collaboration likewise shifts from counting enterprise participation to jointly defining deliverable quality, while the college retains primary responsibility for education and assessment.

This manuscript is a curriculum-reform design study and does not present student grades, questionnaires, or enterprise-evaluation data that have not actually been collected. Whether the reform improves structure–property transfer, compliant behavior, and occupational understanding must be examined through sustained implementation, learning-outcome analysis, and sampled enterprise review. Subsequent research should report effective and ineffective elements as well as implementation costs and should revise the curriculum in response to updates in the pharmacopoeia, regulation, industry technology, and student preparation.

Only when students repeatedly engage in authentic or near-authentic quality tasks—understanding drugs, consulting standards, respecting facts, working compliantly, and accepting responsibility—can Medicinal Chemistry fulfill its role as a higher vocational foundation course that connects prior and subsequent learning, transforms knowledge into action, and develops ethical responsibility alongside technical competence.

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Conflict of Interest
The author declares no conflict of interest.

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