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Advancing Organic Chemistry Education: Strategies for Fostering Excellence and Innovation

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Abstract: In the realm of chemical and chemical engineering disciplines, Organic Chemistry stands as an indispensable foundational course, underpinning the essential theoretical knowledge and experimental prowess required. The acquisition of competencies in this subject is deemed critical for the further academic and professional progression of students. Addressing the intrinsic attributes of Organic Chemistry, the pedagogical reform adopted encapsulates a blend of professional integration, elucidation of complexities, knowledge augmentation, and the infusion of research-oriented activities. This pedagogical stance is designed to kindle a profound interest in Organic Chemistry among students, fostering their autonomous learning capabilities. Concurrently, an array of instructional methodologies is employed within the classroom setting, encompassing knowledge dissemination through lectures, engagement in teacher-student interactions, facilitation of dialogues, and orchestration of group discussions. These are further complemented by an array of post-class activities, including practice exercises, problem-solving reviews, collaborative discussions, and intermittent evaluations. This multifaceted educational strategy has been instrumental in enhancing the efficacy of instruction, with the objective of amplifying the caliber of science and engineering education.

1. Introduction

Organic Chemistry, as an essential foundational course, is integral to the curriculum for students pursuing degrees in the fields of chemistry and chemical engineering within higher education institutions. The discipline's core theories are indispensable for the guidance and advancement of the contemporary chemical and chemical engineering sectors. Focused on the investigation of organic substances' composition, structure, properties, synthesis, and application, the Organic Chemistry course aims to acquaint students with the foundational theories of modern Organic Chemistry. The curriculum is designed to blend theoretical insights with practical laboratory experiences and real-world applications, thereby ensuring that students not only comprehend the fundamental principles of Organic Chemistry but also acquire proficiency in organic synthesis methods and techniques. This pedagogical approach is committed to nurturing a rigorous and scientific attitude towards learning, enhancing students' abilities to independently analyze and resolve issues, and establishing a robust groundwork for their subsequent academic endeavors.

The teaching and learning of Organic Chemistry currently face significant challenges, primarily due to the intricate nature of the subject and the traditional pedagogical models employed. The subject is characterized by its extensive array of concepts, the complexity of reaction formulas, and the obscure nature of reaction mechanisms, which collectively contribute to the difficulty of teaching and understanding Organic Chemistry. Additionally, the predominant teaching model, heavily reliant on instructor-led lectures with limited opportunities for active student engagement, often results in a tepid classroom environment, scarce interactions between teachers and students, and a notable lack of learning motivation among students. This situation detrimentally impacts the quality of education. To address these challenges, it is imperative to pursue continuous innovation and enhancement in Organic Chemistry education. Furthermore, integrating modern pedagogical strategies, such as active learning techniques, technology-enhanced teaching tools, and interdisciplinary approaches, can significantly enrich the learning experience [1]. By doing so, educators can invigorate classroom dynamics, foster deeper student engagement, and ultimately elevate the overall educational quality in Organic Chemistry.

2. Current Status of Organic Chemistry Education

At present, Organic Chemistry education in some higher education institutions faces several challenges:

2.1. Weak Foundation in Chemistry

The widespread adoption of the new college entrance examination system in China, which allows students to select their subjects, has led to some students not choosing chemistry. As a result, these students cease their study of chemistry after the high school chemistry exam and do not engage with the subject again before entering university. This situation presents significant difficulties for students with a weak foundation in chemistry when attempting to complete the teaching tasks outlined in the "Organic Chemistry" (Sixth Edition) textbook, authored by the Organic Chemistry Teaching and Research Department of Tianjin University, within the allocated 80 hours of instruction. Adhering to the standard teaching plan could result in these students only acquiring a superficial understanding of the subject. Given the closely interlinked knowledge across different chapters of Organic Chemistry, a lack of solid foundational knowledge can make learning subsequent chapters increasingly challenging. Relying solely on rote memorization is insufficient for mastering the complex concepts and principles of Organic Chemistry.

2.2. Differences in Major Requirements and Teaching Needs

Organic Chemistry, a fundamental compulsory course for a broad range of disciplines, is integral to undergraduate programs such as chemical engineering and technology, applied chemistry, pharmaceutical engineering, polymer materials and engineering, environmental engineering, energy chemical engineering, and bioengineering. Beyond acquiring a basic understanding of Organic Chemistry, each major has specific requirements for the course. For instance, chemical engineering and pharmaceutical engineering emphasize synthesis, polymer materials and engineering focus on polymerization, environmental engineering is concerned with the properties and applications of organic compounds, applied chemistry highlights organic analysis, and bioengineering and biotechnology prioritize sugars and amino acids. If instructors do not account for these disciplinary differences during the teaching process and adopt a one-size-fits-all approach, it will inevitably be challenging to achieve the desired educational outcomes.

2.3. Heavy Learning Tasks and Low Student Interest

The content of Organic Chemistry is complex and filled with intricate details. Teachers are challenged to complete their teaching tasks within limited class hours, presenting students with significant learning challenges. Students are required to assimilate centuries of disciplinary knowledge accumulated by humanity within just a few months, leaving little time for a deep understanding of the material [2]. Teachers, on the other hand, face the dilemma of balancing the ever-expanding subject matter with the continuously shrinking allotted class time. In the pursuit of teaching efficiency, knowledge is often imparted merely as a result, without providing students an understanding of its origins, value, and significance. This approach leads to a loss of interest in learning, diminished motivation, and a tendency among students to resort to rote memorization for exams. Such practices starkly contrast with the educational goal of applying organic knowledge in science and industry, further exacerbating the gap between teaching objectives and outcomes.

2.4. Insufficient Integration of Cutting-Edge Disciplinary Content

The current editions of "Organic Chemistry" textbooks predominantly cover basic theoretical knowledge and fundamental organic reactions. Despite reforms and innovations in textbook content, which have led to the inclusion of a small amount of cutting-edge research findings in some editions, these textbooks still fail to keep pace with the latest advancements in scientific research. Therefore, incorporating the most recent scientific developments into the Organic Chemistry curriculum is crucial for sparking students' interest in learning, broadening their knowledge base, and enhancing the overall quality of Organic Chemistry education.

Drawing on years of teaching experience, this article aims to achieve the educational objectives of the Organic Chemistry course by ensuring the curriculum is sufficiently challenging to stimulate students' interest and proactive engagement in learning. This aligns with the Outcome-Based Education (OBE) teaching philosophy. A comprehensive curriculum design is proposed, focusing on teaching strategies, assessment and feedback, and learning support, to foster an environment where students are motivated to explore and engage deeply with the subject matter.

3. Setting Multidimensional Educational Goals

In alignment with the specific requirements of various professional training programs and a comprehensive analysis of student learning scenarios, objectives encompassing knowledge, capabilities, and qualities have been meticulously established. These objectives are delineated as follows:

1) It is envisaged that through diligent engagement with this course, students will be equipped to construct a coherent knowledge framework of Organic Chemistry. This includes mastering the fundamental concepts, theories, and reactions pivotal to Organic Chemistry, alongside accurately naming and structuring common compounds. Such foundational prowess is anticipated to underpin the learning of subsequent specialized courses, enabling students to resolve chemical issues encountered in daily life and professional contexts with precision and efficacy.

2) The course is designed to facilitate students' understanding of the intricate relationship between the structure and properties of organic compounds and to hone their ability to employ analogous research methodologies. Students are expected to harness the characteristics of functional groups to devise testing methods for organic compounds, deduce the structures of organic compounds grounded in experimental evidence, and design, compare, and select synthetic pathways

for various compounds informed by their preparatory methods. Furthermore, through the analysis of factors impacting chemical engineering and its processes, students will acquire a profound understanding of the essence of complex chemical engineering dilemmas, culminating in effective conclusions for addressing intricate engineering challenges within the sphere of chemical engineering.

3) By partaking in this course, students are encouraged to independently consult scientific literature, elucidating both the positive and adverse impacts of Organic Chemistry on humanity. This includes grasping the significance of rigorous scientific attitudes and exalted professional ethics for researchers and paying heed to the implications of chemical engineering practices on human health, the natural environment, and societal safety.

4. Implementing Curriculum Reforms Aligned with the OBE Teaching Philosophy

The core teaching ethos of this course is predicated on a student-centered, outcome-oriented approach, advocating for the continuous enhancement of instructional methodologies in adherence to the Outcome-Based Education (OBE) teaching philosophy. Throughout the educational process, a pronounced emphasis is placed on affirming the principal role of students, stimulating their initiative, kindling their interest in the subject, and focusing on cultivating their logical thinking capabilities. This course is focused on achieving defined educational goals through a tripartite teaching model: "pre-class preparation, in-class instruction, and post-class exercises and tutoring." Efforts are made to optimize course content, leveraging digital technologies for modular education and crafting a strategic route for Organic Chemistry teaching reform. This includes incorporating cutting-edge advancements, elucidating challenging concepts, integrating professional relevance, engaging with research, and broadening knowledge bases. Predominantly centered on in-class teaching, supplemented by pre-class preparation and post-class tutoring, and employing modern information technologies, an interactive teaching model between instructors and students is developed. By assessing and providing feedback on learning outcomes, the course aims to amplify its teaching efficacy, addressing the prevailing instructional challenges, and nurturing a cadre of high-quality, multifaceted talents with enhanced practical and innovative capabilities, poised for global competition.

4.1. Strengthening Pre-Class Preparation

Pre-class learning is characterized by students' proactive utilization of relevant knowledge and learning abilities to explore, question, and ponder new information prior to attending lectures. According to educational psychologist Jerome Bruner, learning is an active process of discovery, not passive receipt; it involves the organization and reorganization of cognitive structures, with learners actively acquiring and integrating new with existing knowledge [3]. Pre-class preparation significantly empowers student autonomy, facilitating independent and effective learning endeavors. Tailored to the diverse requirements of Organic Chemistry across various majors and integrating the course's instructional process, pre-class tasks may encompass content for a chapter, section, or specific concepts and reactions. Utilizing online educational platforms to assign pre-class tasks encourages students to investigate new topics, uncover issues, think independently, consult literature, apply knowledge, and synthesize information [4].

4.2. Enhancing Classroom Efficiency

The classroom serves as the primary locus of student learning, with students acting as both the subjects and the masters of their educational journey. Instructors, through their pedagogical artistry and control, exploit the advantages of traditional lecturing while introducing innovative teaching methodologies and modes. This encompasses direct instruction, inductive reasoning, and discussion, avoiding monolithic explanations, enriching content delivery, and reforming teaching methods. Organic Chemistry instruction employs a variety of classroom teaching modes, including review of prior knowledge, introduction of new material, detailed explanations, student-teacher interaction, problem discussion, and group debates [5]. This multifaceted approach not only facilitates the review of previous knowledge and strengthens the mastery of the Organic Chemistry knowledge system but also ignites students' enthusiasm for learning and lays a solid foundation for successful lessons.

4.3. Post-Class Exercises and Review

Review sessions are imperative, because of the interconnected nature of Organic Chemistry chapters. Such reviews help students organize the key points, difficulties, and overall framework of the chapter, familiarize themselves with the teaching outline, and master the relevant concepts. Post-class exercises and review serve as an extension of classroom instruction. These activities, which may include problem-solving exercises, online solutions, group discussions, and periodic tests. Targeted exercises on key and challenging topics deepen understanding; personalized teaching approaches are employed to address the queries of students facing difficulties, utilizing advanced information technology platforms like XuetangX, Rain Classroom, and WeChat for online clarification, thereby preventing knowledge gaps and smoothing the path for future learning endeavors. Discussions among students reveal common and unique challenges encountered during their studies. These discussions not only enhance comprehension of the subject matter, foster teamwork and communication skills, and strengthen bonds among peers but also significantly boost students' interest in learning.

5. Integrating Ideological and Political Elements into the Curriculum

General Secretary Xi has emphasized at the National Conference on Ideological and Political Work in Universities that "The essence of higher education lies in fostering virtue through education. It is essential to regard moral education as the central link, integrate ideological and political work throughout the entire educational and teaching process, and achieve comprehensive and all-round education." In this vein, efforts are continually made to seamlessly incorporate ideological and political education into the Organic Chemistry curriculum, achieving the dual objectives of "teaching" and "educating," and deeply integrating educational and moral development. When introducing the course, it's important to cover the history of Organic Chemistry, selectively highlighting the outstanding achievements of Chinese scientists, such as Mr. Huang Minglong, who is a pioneer in China's steroid hormone pharmaceutical industry. His modified Wolff-Kishner reduction is the first important organic reaction named after a Chinese scientist, showcasing the contributions of Chinese scientists to the nation and fostering a sense of national pride and patriotic sentiment among students. Organic compounds play a crucial role in societal development, yet their pollution is not uncommon. When discussing alkene compounds, the ripening effect of ethylene in production is mentioned as an example, indicating that while moderate use is safe, excessive application can lead to health hazards like vomiting and nausea, highlighting the importance of responsible scientific practice. From a life-oriented perspective, this approach aims to spark scientific curiosity in students, helping them recognize that technology is a double-edged sword. It guides students to establish correct values and consciously fulfill their social responsibilities towards health safety and environmental protection.

6. Utilizing Diverse Resources Efficiently

In the context of course instruction, there is a proactive drive to integrate modern information technology deeply with pedagogical practices. Utilizing resources such as the Organic Chemistry online open courses available on China's MOOC platform enriches the student learning experience with a variety of modules, including knowledge acquisition (course materials and videos), consolidation exercises (video-synced exercises and chapter reviews), assessments (unit tests), and discussions (online forums). Students are guided to make full and rational use of these resources. To ensure educational objectives are met, platforms like Superstar Learning Pass offer students access to reference materials, homework banks, question banks, and feedback on outcomes. Diverse methods, including WeChat, Learning Pass, MOOCs, and face-to-face sessions, are employed for pre-class and post-class guidance.

Leveraging the exceptional academic resource of the Organic Chemistry research team, students are taken on visits to research groups to diminish the perceived distance between them and scientific research. Additionally, using database platforms purchased by the library, students are encouraged to conduct literature reviews and summaries on relevant cutting-edge developments, enhancing the purposefulness and enjoyment of learning. In-class discussions start from the forefront of advancements, integrating the latest research findings in Organic Chemistry with classical theories in the textbooks to stimulate student interest, develop problem-solving skills, and deepen their understanding of the application of foundational knowledge in Organic Chemistry at the forefront of the field [6].

7. Establishing a Reasonable Evaluation Model

This course implements formative assessment aligned with educational goals, ensuring each assessment method explicitly supports specific course objectives. In addition to attendance and regular assignments, varied forms of assessment, such as mid-term tests and course papers, place greater emphasis on comprehensive evaluation of students' learning progress and innovative capabilities. Assessments aim to enhance student engagement and interest, with a student-centered approach by instructors. During mid-term evaluations, students are encouraged to create questions based on the distribution of knowledge points in the textbook and conduct peer reviews in groups. For course papers, numerous questions are set within each topic of the specialized teaching modules, allowing students to choose based on personal interest for literature research, analysis, and report writing. The implementation of this new model has significantly increased students' active participation and desire to learn, both in and out of class. Through active and earnest participation in these assessment components, students are positioned to achieve commendable academic outcomes over the semester.

8. Conclusions

Under the New Engineering Education framework, the exploration and practice of teaching Organic Chemistry have led to revisions in the curriculum system, teaching outline, content, and tasks. This reform encourages pre-class preparation through task assignments, regular check-ins, online Q&A, and diverse evaluations, enhancing students' self-directed learning abilities, problem identification and research skills, thus boosting their learning initiative. Classroom instruction has been improved with methods such as reviewing background knowledge, introducing new topics, delivering knowledge, facilitating teacher-student interactions, exchanging problems, and conducting group discussions. Post-class reviews, including homework, exercise drills, online solutions, group discussions, and periodic tests, enable students to grasp key concepts, deepening the teaching process. This shift from "receptive learning" to "discovery learning" and from "mechanical memorization" to "interest-driven learning" marks a fundamental transformation from traditional teaching methodologies. This innovative approach not only cultivates a strong interest in Organic Chemistry among students but also enhances their self-learning capabilities and teaching outcomes. It fosters students' research curiosity and innovative thinking, preparing them to meet the demands of emerging industries and the new economy. This model aims to develop high-quality, versatile talents with enhanced practical and innovative skills and international competitiveness.

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