

Practice and Exploration of Joint Training of Inter-Disciplinary Talents in Science and Engineering

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Abstract

As two famous universities in China, Nankai University and Tianjin University combine their own advantages on chemistry and chemical engineering, respectively, to establish the specialty of “Molecular Science and Engineering” since 2001 in accordance with the requirements of “independent organizing, close cooperation” towards the education of inter-disciplinary talents. The two universities recruit 30 undergraduates each year. In the first two years, they study chemistry together in Nankai University, and in the second two years, they are taught and trained chemical engineering in Tianjin University. When graduating, they are awarded two bachelor’s degrees in both science and engineering. The students majoring in Molecular Science and Engineering have both science and engineering background, solid theoretical foundation, strong practical innovation ability, broad employment prospects, and are generally praised by employing units. In 2020, Molecular Science and Engineering has been selected as the national first-class specialty construction site, which has become the professional benchmark for the cultivation of interdisciplinary talents.

Keywords

Molecular Science, Chemistry, Chemical Engineering, Double Bachelor’s Degrees, Interdisciplinary

1. Introduction

The diverse world of biological universe and even ourselves are built on small molecules. Both chemistry, as a fundamental of science, and chemical engineering, as a practical science of engineering, need to start with molecules. In the current era of rapid development, various traditional disciplines are highly cross-

integrated, and the demand for talents is increasingly transitioning from single type to interdisciplinary type. With molecules as the link, we can connect science and engineering, chemistry and chemical engineering, which are closely related to social development, national economy and people's livelihood.

2. Historical Evolution

2.1. Background of Molecular Science and Engineering Specialty

In order to cultivate science and engineering interdisciplinary professionals to adapt to the new situation of the modern science, engineering and industry, the College of Chemistry of Nankai University and the College of Chemical Engineering of Tianjin University, with the geographical advantages of being adjacent to each other have made full use of their own advantages to build up a brand-new specialty namely "Molecular Science and Engineering" since 2001. The Molecular Science and Engineering specialty was organized in a new mode of "independent organizing, close cooperation", aiming to raise the students with a combination background of both chemistry and chemical engineering. To encourage the new cooperation mode between chemistry discipline and chemical engineering discipline, the Ministry of Education (MOE) of China set up a new professional code "070304T" for the specialty.

Molecular Science and Engineering has enrolled the first batch of students since 2003. Each university recruit 30 students through the college entrance examination and a further selection test every year. The two universities have established an innovative cross-campus training mode for the student of Molecular Science and Engineering specialty. During the 4-year undergraduate study, the 60 students were trained in a centralized and unified way, and a two-year rotation system was implemented, that is, they study chemistry together in Nankai University in the first two years and study chemical engineering in Tianjin University in the last two years. The two universities regularly hold joint meetings, and the academic affairs offices, college leaders and teaching management personnel analyze the running situation, summarize experience, and timely reform and update the training mode and training details. The guidance of graduation thesis and the examination of graduation qualification are jointly undertaken by the two universities. Students can freely choose their graduation project topics and tutors in either College of Chemistry of Nankai University or College of Chemical Engineering of Tianjin University.

2.2. Development of Molecular Science and Engineering Specialty

The chemistry discipline of Nankai University and the chemical engineering discipline of Tianjin University have joined hands to forge ahead and gained a series of successful experiences. "Reform and Practice of Cross disciplinary Talents Training in Chemistry and Chemical Engineering" was listed as the key project of higher science and engineering education reform and practice of the Ministry of Education of China in 2006, and was rated as excellent at the acceptance. In

2009, “Reform and Practice of the interdisciplinary talents of science and engineering” won the second prize of the National Teaching Achievement Award. In 2017, it was rated as Tianjin’s advantageous specialty, and in 2018, “the Establishment and Implementation of a Collaborative Education Mechanism for Cultivating International Innovative of Chemistry and Chemical Engineering Talents” won the first prize of Tianjin’s teaching achievements (Figure 1). After 20 years of construction and development, “Molecular Science and Engineering” has trained more than 1000 graduates so far. The exploration and practice of this new science and engineering composite specialty has opened up a new way for China to cultivate high-level interdisciplinary talents. In 2020, Molecular Science and Engineering was selected as the national first-class specialty construction site, and was designated as the core specialty of key construction by the State and the Ministry of Education.

3. Why Combining Chemistry and Chemical Engineering

3.1. Target

Molecular Science and Engineering specialty has a clear goal since its inception. The specialty tightly combines chemistry and chemical engineering, and on this basis, integrates and innovates, optimizes the teaching content of chemistry and chemical engineering, increases the characteristic interdisciplinary knowledge, and cultivates indomitable high-level interdisciplinary talents with the ability of scientific research, product development and industrialization. The graduates should meet the needs of science and technology development, have broad and profound foundation in chemistry and chemical engineering, can solve major engineering problems, have a strong sense of innovation, and open a broad international vision.

3.2. Advantages

As the first specialty to explore the cultivation of interdisciplinary talents in

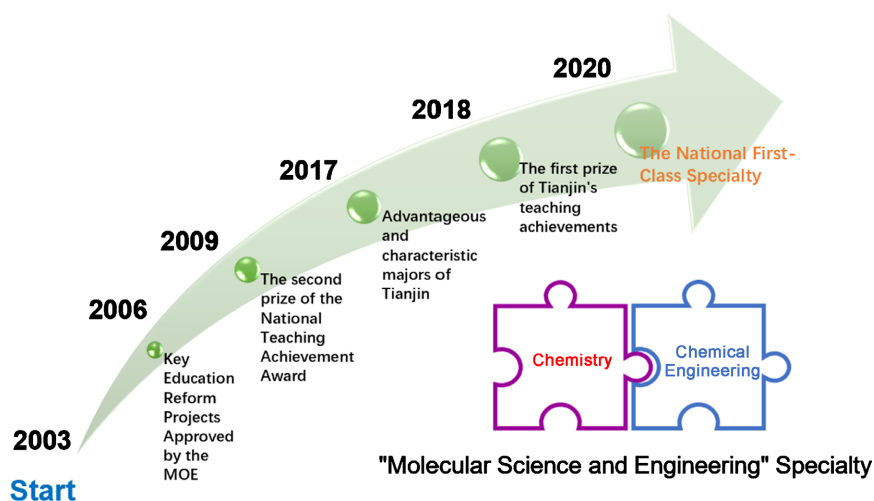


Figure 1. Development history of the molecular science and engineering specialty.

China, Molecular Science and Engineering has demonstrated its unique advantages and characteristics in the past 20 years of construction. At present, Molecular Science and Engineering has established a complete set of systems to cultivate interdisciplinary talents from the joint enrollment of the two universities, the establishment of student status, the coordination and innovation of the curriculum, the designation of credit rules, to the establishment of a reasonable join and quit mechanism, the improvement of the reward and punishment system, the selection of graduation projects by students at different colleges and departments, and the assistance of graduates in the designation of career plans according to their own characteristics, through continuous exploration, practice, reform and innovation. It has become a benchmark for the cultivation of interdisciplinary talents in China. Molecular Science and Engineering employs well-known experts outside the university to set up a professional teaching steering committee to regularly review, revise and improve the professional talent training program, so as to provide guarantee for improving the quality of professional talent training. The professional rules and regulations are sound and complete, and a closed-loop teaching quality assurance system of “operation, guarantee, supervision, reward and punishment” has been formed, which provides a guarantee for high-level teaching quality.

In terms of curriculum construction, Molecular Science and Engineering optimizes the curriculum content according to the characteristics of the specialty, arranges the semester according to the characteristics of the specialty and the difficulty of the course reasonably, highlights the core basic courses covering chemistry and chemical engineering, such as General Chemistry, Chemical Engineering Thermodynamics, Chemical Reaction Engineering, etc. Teachers of the two universities teach in each other's colleges according to the curriculum settings. On this basis, we integrate chemistry and chemical engineering courses and combine the characteristics of composite specialty to offer brand new courses with distinctive features, to promote the integration of students' thinking in chemistry and chemical engineering, highlight the characteristics of the specialty, and effectively combine national strategic needs and scientific and technological frontiers closely related to the specialty, such as Comprehensive Chemical and Chemical Experiment, Molecular Design and Product Engineering, Molecular Science and Engineering Informatics, etc. In addition, in view of the specialty characteristics and students' learning process, the two universities jointly set up characteristic elective courses, such as Green Chemistry Foundation, Chinese Medicine Engineering Foundation, Energy and Chemical Engineering Foundation, and Chemical Engineering Problems in Biomacromolecule Research, to encourage students to choose courses and develop their own training mode according to their own interests and future plans.

The “1 + 2” certificate system is implemented for the students of the Molecular Science and Engineering who have completed their undergraduate learning tasks and graduation design, that is, when they graduate, they can obtain the

graduation certificate of the university where they are enrolled, and obtain the double bachelor's degrees of science from Nankai University and engineering from Tianjin University. In terms of graduate recommendation, the policies of the two universities are inclined to the specialty, and the proportion of postgraduate admission can reach 40%. Students, regardless of their status in Nankai University or Tianjin University, can freely choose the direction of postgraduate in the two universities.

4. Faculty and Training System

4.1. Teachers, Courses and Practice

The two universities provide the strongest teachers for the Molecular Science and Engineering specialty (Ye, Wang, Li, Cheng, Zhu, & Guo, 2021), including academicians, famous teachers, and a group of outstanding young talents, and three national teaching teams for inorganic chemistry, chemical experiment series courses and chemical engineering practice (Figure 2). National famous teacher, academican of Chinese Academy of Engineering, Distinguished Professors of MOE, and several national young talents and are directly involved in the construction, teaching and scientific research training projects of the specialty. Molecular Science and Engineering is a collection of excellent courses. Through the continuous elimination of “useless courses” and the creation of “golden courses”, the systematic education of four level excellent courses, namely national, municipal, university demonstration, and university has been formed (Qiu, Zhu, Ma, & Cheng, 2021). Students can enjoy 6 national excellent courses, 6 national first-class undergraduate courses, 8 Tianjin excellent courses, 2 national excellent video open courses, 7 national excellent resource sharing courses, and 7 Tianjin first-class undergraduate construction courses.

The Molecular Science and Engineering specialty attaches great importance to integrating theory with practice, applying knowledge to practice, combining and promoting learning with practice (Ruan, Jiang, Zhang, Li, & Zhu, 2023). Relying on chemistry and chemical engineering, two first-class construction disciplines, three national key laboratories, and three national engineering centers, a high-level scientific research training platform is built to carry out multi-level scientific research training (Figure 2). For example, the freshman should participate in “I Love the Laboratory” activities and a month of “Summer Scientific Research Training” to experience scientific research. The sophomore students are encouraged to apply for the National Undergraduate Innovation Project, Tianjin Undergraduate Innovation Project, Nankai University's “Hundred Projects” and other projects, select topics independently, and exercise their scientific research ability and innovation awareness; The junior enters the corresponding research group to carry out scientific research practice for two months, complete the project and submit the research report. In addition, we encourage and recommend students to participate in international summer schools or overseas research training programs.

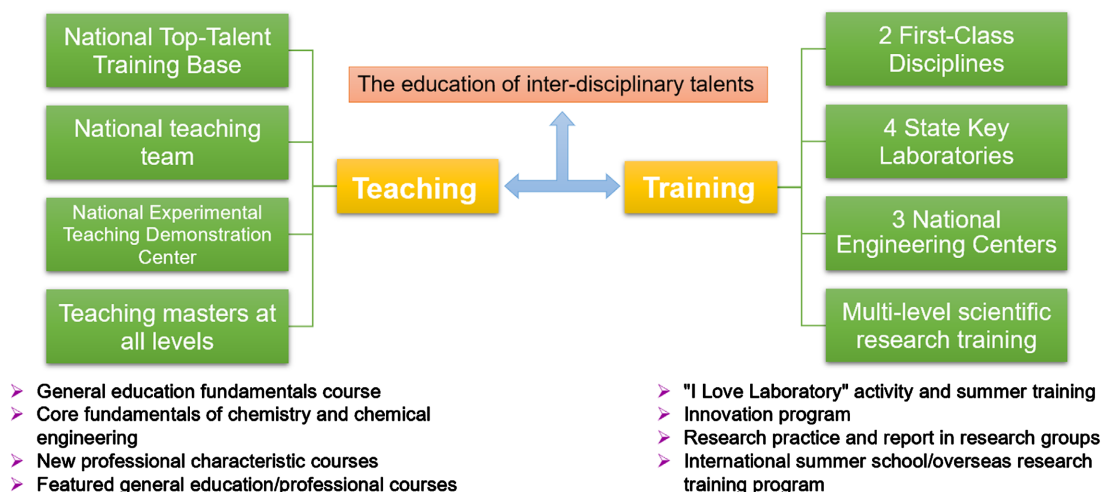


Figure 2. Education and training system of the Molecular Science and Engineering specialty.

4.2. Employment Prospects and Talent Training Achievements

The students majoring in Molecular Science and Engineering have both the science background of Nankai University and the engineering background of Tianjin University, so they have a broad graduation destination and choice space (Kluger & Bartzke, 2020). According to the combined tracking statistics from the College of Chemistry of Nankai University and the College of Chemical Engineering of Tianjin University towards the 251 graduates in recent five years, about 54% of students are recommended or admitted to Peking University, Tsinghua University, University of Chinese Academy of Sciences and other famous domestic universities every year; About 15% of graduates go to international first-class universities such as UCLA, MIT and Stanford for further study; About 31% of graduates work in internationally renowned chemical or chemical engineering enterprises and national key institutions (Figure 3).

The specialty of Molecular Science and Engineering has trained a group of science and engineering interdisciplinary high-quality talents with a solid foundation, engaged in cross scientific research, adapting to major national needs, possessing strong innovation consciousness and the ability of product development and industrialization. The graduates have been widely praised by employing units because of a solid theoretical foundation and strong practical innovation ability. According to interviews with five professors from the College of Chemical Engineering at Tianjin University who have or have had the graduate students in their groups, compared with the students from the traditional engineering majors, graduate and/or PhD students from the specialty of Molecular Science and Engineering exhibit obviously show a strong ability to think and explore problems from the view of a solid chemical base, and have great potential for development of chemical engineering research.

Among the first graduates of Molecular Science and Engineering, Li Yanran received a doctor's degree from University of California, Los Angeles, and successively engaged in post-doctoral research at California Institute of Technology

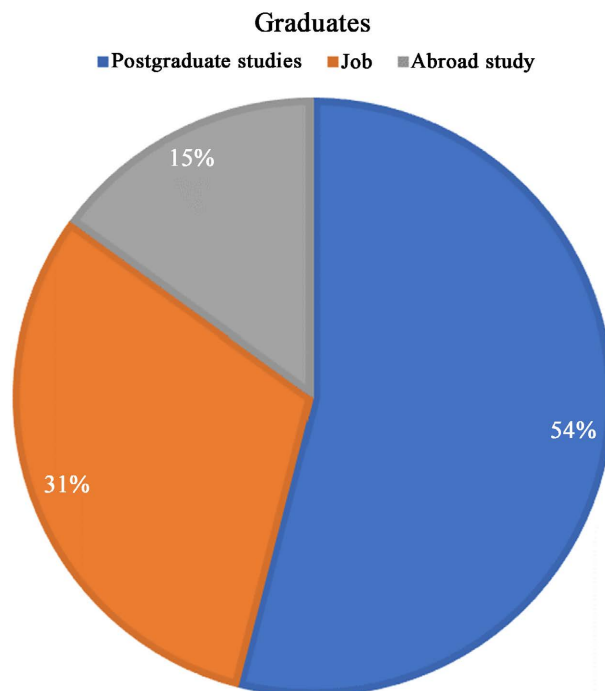


Figure 3. Career statistics of the graduates from Molecular Science and Engineering specialty.

and Stanford University. In 2016, she got the teaching position at University of California, Riverside ([University of California, Riverside, n.d.](#)), and was awarded the professor position since 2023. Dr. Zhu Jian, who received a doctor's degree from the University of Michigan, Ann Arbor, carried out postdoctoral research in Northwestern University, is currently a professor at the College of Materials Science and Engineering, Nankai University. Dr. Zou Ruiyang, who won the gold medal of the "International Genetic Engineering Machine Design Competition" in 2007, started his business in 2016 after obtaining the PhD degree from the joint-supervision project of National University of Singapore and MIT. Now he is the chief technology officer of Mirui (Hangzhou) Biotechnology Co., Ltd., developing cancer clinical diagnostic kits, and has been listed in Forbes China's Top 100 Global Chinese Elite. Dr. Zhang Yumiao, a graduate of Molecular Science and Engineering specialty in 2010, is now a professor at the College of Chemical Engineering of Tianjin University.

5. Challenges and Limitations

For the students of Molecular Science and Engineering, the greatest challenge to graduate and obtain the double bachelor's degrees of both science and engineering, is the heavy coursework. The four-year chemistry courses and four-year chemical engineering courses are compacted into the two-year and two-year course system, indicating the concentrated courses and time the students should be facing. The required credits for students of Molecular Science and Engineering was 209 before 2013, while the credits required for the normal chemical spe-

cialty is only 147.5, which means that the students of Molecular Science and Engineering have relatively less time for other activations and arrangements such as preparing for Graduate Entrance Examination, TOEFL and GRE. Several students were “scared” by the heavy courses and hesitated due to the limit of free time when applying for majors. After symposium with the students, three main reform measures were carried out: 1) set up professional mentors to guide the students making a suitable academic plan; 2) invite previous students as the specialty guide to help the new students gradually adapting the major studies; 3) streamline courses to both reduce the course load and ensure the “precising study”, and the required credits for students of Molecular Science and Engineering was reduced from 209 to 192. Positive feedback for these measures was received from the students, and the number of specialty applicants increased significantly.

The idea of molecular science and engineering for the education of inter-disciplinary has attracted considerable interest and following. Currently, there are 7 Molecular Science and Engineering specialties established in Chinese universities, and several universities such as Peking University have set up the college of Molecular Science and Engineering. However, the Molecular Science and Engineering specialty by Nankai and Tianjin university is still the only one joint-constructed by two universities, while the others are just established within a single university. The main limit for other universities to have the joint-specialty is the position. When establishing, Nankai and Tianjin university are neighbors with each other, thus it is very convenient for the students to exchange and communicate under the unified management. Nevertheless, most of the other universities do not possessing this geographical advantage. Now this limit may be covered along with the development of the virtual technique: more and more virtual simulation courses have been built up, and the increasingly mature online courses and teaching models gradually change the traditional education manners, which should significantly reduce or even eliminate the impact of distance between cooperating universities and promote the development of the inter-disciplinary among universities with different characteristics to meet the demand for interdisciplinary talents by the modern society.

6. Conclusion and Outlook

Currently, the interdisciplinary integration is becoming more and more important due to the requirement of the modern scientific and engineering innovation in both research institutes and industries or companies (Van Noorden, 2015). In 2023, The Molecular Science and Engineering specialty has been 20 years since it admitting the first class of students, and the successful construction and development of this unique specialty unambiguously present the necessity and advantage in the combination of chemistry and chemical engineering, which provides a new route in the high education of students with both reliable scientific fundamentals and strong engineering skills. Next, the specialty will follow a fur-

ther innovation and improvement on the training model to make a combination involving chemistry, chemical engineering, and the international industries and companies, aiming to raise internationalized composite talents in science, engineering, and enterprise, and look forward to the future and stride towards new goals bravely.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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