

## Reform and Practice of Analytical Chemistry Teaching under the New Engineering Paradigm

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**Abstract:** The construction of the new engineering paradigm involves four aspects of industrial demand, engineering practice, interdisciplinary integration and innovation capacity, which demands the cultivation of high-level talent in chemical engineering, environmental science, materials science and other fields. Based on the connotation of new engineering development, this paper aims at solving the existing problems in analytical chemistry education. This paper proposes the teaching reform scheme from the following aspects: systematically reconstructing the teaching objectives and optimizing the teaching content; deeply integrating the ideological and political education; establishing a diversified evaluation system. The goal of these reforms is to change the approach to analytical chemistry from a “knowledge-transmission course” to a “competency-development course”, and finally to an “educational triad of knowledge dissemination, skill cultivation and value formation”.

**Keywords:** New Engineering; Analytical Chemistry; Teaching Reform; Ideological and Political Education; Blended Learning

### 1. Introduction

The new engineering project is a major strategic move by the Chinese government in response to the latest round of technological revolution and industrial transformation [1], and is a move that promotes the intrinsic development of higher education. It seeks to break away from the traditional engineering education model which emphasizes theoretical knowledge at the expense of practical ability [2], and to build a new talent cultivation model focused on the industry, solving complex engineering problems based on

multidisciplinary fusion. This system focuses on strengthening the engineering practice skills [3-5], technological translations, innovative thinking, teamwork and social responsibility of the students [6-7].

Yet, the traditional teaching methods have been “entrenched” into a relatively stereotypical teaching model that is obviously different from the requirements of new engineering: teaching is dominated by a teacher-centered approach, teaching content is formulaic, students passively receive knowledge, and the experimental teaching is a step-by-step verification process; the teaching content is still traditional, with little coverage of cutting-edge technology, Chinese instruments, and industrial standards; ideology and politics are superficially added to the teaching content, and the final examination is used as a major tool for teaching evaluation. Together, these problems result in students who “know but cannot apply, apply without rigor, and apply without innovation” and who do not meet the new goal of engineering talent cultivation [8,9].

Accordingly, in this paper, all pedagogical problems are carefully analyzed, and the competency framework required by the new engineering is taken into account to devise a comprehensive, systematic and implementable reform blueprint for analytical chemistry education. This blueprint aims to further enrich and advance the course in terms of its sophistication, innovativeness and rigor so as to foster the development of quality talents for the new engineering era.

### 2. Core Challenges in Analytical Chemistry Teaching under the New Engineering Context

In the context of emerging engineering construction, there exist five prominent bottlenecks in the teaching of analytical

chemistry, as presented in Figure 1.



**Figure 1. Core Challenges in Analytical Chemistry Teaching under the New Engineering Context**

### **2.1 Disjunction between Principles and Technology, Overemphasis on Theory at the Expense of Engineering Application**

Traditional teaching and learning in the field of analytical chemistry has always focused on theoretical aspects, and it is taught mainly on the principles of titration, the derivation of formulas, the reaction equations and calculations, lacking in engineering level technology. This results in students scoring high on exams, yet not knowing how to apply their knowledge in the real world of engineering, and a lack of engineering insight, translation, and application, which is not aligned with the new engineering focus on technological transformation.

### **2.2 Separation of Laboratory Teaching from Engineering Practice, Emphasis on Verification over Design and Innovation**

Analytical chemistry laboratory teaching is a core component in developing students' practical skills. However, in most experiments, critical thinking, design, judgment or optimization are not required and students only follow the procedure: sampling, addition of reagents, titration, measurement of data, tabulation of data, writing of report.

This rote experimentation does not help develop engineering cognition, innovative thinking and problem-solving skills. The graduates therefore lack significant skills when faced with actual samples, complex matrices, field situations and new problems, and are thus not prepared for work as an engineer.

### **2.3 Curriculum Content Lagging behind Industrial Demands and Frontier Developments**

The new engineering paradigm involves new areas such as new energy, advanced materials, biomedicine, artificial intelligence, environmental governance, and intelligent manufacturing, which also have high

requirements for fast and intelligent analysis technology. However, current textbooks and curricula are not updated in time and mainly cover the four traditional titration methods, lacking frontier techniques.

Furthermore, the mismatch between the content of the lesson and the standards of enterprises, projects and actual testing process means that students don't know how to go and work in enterprises, lack of understanding of the nation's standards and the enterprise's norms, which leads to the phenomenon of students' learning and going to work separately [9].

### **2.4 Superficial Integration of Ideological and Political Education, Insufficient Value Guidance**

Ideological and political education is an important part of value cultivation in the process of cultivating new engineering talents. Regardless, it is used superficially in the classroom, frequently appearing as a simple juxtaposition of ideological components and subject matter, such as the scientists' biographies in the environment class, pollution in lessons about pollution or honesty in science lessons without an in-depth connection to scientific principles. There is no clear vision of ideology, and core values such as scientific spirit, data integrity, engineering ethics, safety standards, social responsibility, patriotism and technological self-reliance are not aligned with the competencies [2,3,5-6].

### **2.5 Monolithic and Rigid Evaluation System, Overemphasis on Scores at the Expense of Competency and Literacy**

The current evaluation system in analytical chemistry is primarily a "continuous assessment plus final examination" system, where there is not much emphasis on formative assessment, which consists mainly of assignments and attendance. The final assessment is mainly written and based on the ability to remember and compute, rarely testing the skill of designing experiments, working skills in the lab, problem solving, teamwork, innovation or ideologic literacy.

This evaluation paradigm leads to negative consequences: learners do not learn consistently; learners resort to last minute cramming; learners focus more on the theory and less on the practice; assessment does not adequately reflect the broad range of skills needed in new engineering.

Moreover, the results of evaluations are insufficiently fed back to teaching improvements and thus hinder the continuous improvement of teaching. In conclusion, the assessment system is not aligned with the goal of talent cultivation and affects the selection and nurturing of interdisciplinary talents.

### **3. Specific Pathways for Analytical Chemistry Teaching Reform under New Engineering Guidance**

#### **3.1 Reconstructing Teaching Objectives: From “Method Users” to “Technological Innovators and Engineering Practitioners”**

The instructional objectives of analytical chemistry need to be profoundly changed in the new engineering context from the current “to memorize principles, do calculations and operate instruments” to the new “to cultivate analytical technologists with solid theoretical foundations, engineering practice skills, technology translation skills, innovative thinking and professional ethics”. This involves developing an integrated system of knowledge, skills and values, characteristics of scientific rigor, meticulousness and perseverance in service to the National strategies, industrial development and public security [10].

#### **3.2 Optimizing Curriculum Content: Classical Foundations, Engineering Framework, Industrial Orientation, and Frontier Supplementation**

In the new engineering transformation, it is the curricular reform that is the key, which has to transcend the limitations of the textbook and build a quintuple-integrated content system that combines classical methods, engineering technologies, industrial case studies, frontier technologies and ideologies. This change makes the knowledge points dynamic technological chains. This course is based on concepts, and introduces engineering aspects explaining why things work as they do, why they don't and how to make them more reliable or more suitable for engineering applications.

#### **3.3 Deepening Ideological and Political Education: Pervasive Integration and Unified Educational Direction**

Ideological and political education should not be simply added to, but thoroughly integrated into the entire teaching process, ensuring value

guidance permeates every aspect.

**Data Processing:** Teach good practice such as significant figures and error analysis; teach how to treat outliers and present case studies on data fabrication; instill rigour, truthfulness, honesty and responsibility.

**Laboratory Operations:** Emphasize the safe use of chemicals, instruments, waste disposal, and laboratory hygiene, cultivate normative use habits, safety awareness, green low-carbon habits, and environmental awareness of sustainable development.

**Engineering Applications:** Emphasize social responsibility and professional ethics through cases related to food safety, water quality, pharmaceuticals and environmental monitoring, and raise awareness of the analysts' responsibilities to society and a professional ethos of 'quality first, responsibility foremost.

**Frontier Technologies:** Instruct patriotism and technological confidence, and introduce China's achievements in analytical instrumentation, rare earth analysis, lunar exploration, water quality monitoring and standards formulation to inspire the students to serve the country through science and enhance the national pride and self-reliance.

#### **3.4 Establishing a Diversified, Competency-Oriented Evaluation System**

There is a need for a comprehensive overhaul of the system of assessment, moving away from “one shot” final assessment towards a three-part process of continual promotion of learning, feedback to teachers, and continual iterative improvement: formative assessment, assessment of practical skills, and summative final assessment [5].

**Formative Assessment (40%):** Measures activities like the time spent on online learning, participation in class, in-group discussions, number of assignments completed, mapping of concepts, progress reports on projects, as recorded objectively by digital technologies and platforms, thus capturing learning attitudes and processes.

**Summative Final Assessment (60%):** adopts written examination, reduces the amount of rote memorization, adopts case analysis, method selection, experimental design, engineering problem solving, ideological integration, and other types of questions to fully examine the students' comprehensive application ability.

**Ideological and Literacy Observation Points:** This involves incorporating all the evaluation

criteria for data integrity, operation norms, safety and environmental consciousness, responsibility, teamwork and professional demeanor in all the evaluation stages, allowing for the synchronous appraisal of knowledge, skills and values.

#### 4. Anticipated Outcomes of Teaching Reform

Blended, project-based and contextualized pedagogies make classrooms more engaging, as students are no longer passive recipients but active inquirers, which greatly improves interests, participation, and students' autonomous learning ability. Students learn basic laboratory design, and develop initial technology transfer thinking skills that reduce the length of the workplace adaptation period. Project-based teaching and inquiry-based training are effective ways to stimulate innovative thinking, and the number and quality of awards received by students from university innovation and entrepreneurship programs and metallographic competitions have improved significantly. The students' scientific spirit, consciousness about integrity, norms, awareness about the environment, social responsibility, and patriotism are greatly enhanced, the laboratory working system is more standardized, the recording of laboratory data is more authentic, and the teamwork is more harmonious, achieving the synchronous improvement of knowledge, skills, and values.

#### 5. Conclusion

A new engineering paradigm has placed new demands on analytical chemistry education, and has made the traditional educational model based on knowledge transfer insufficient for the development of talents in the modern times. Only with staunch commitment to a student-centered teaching approach, engineering-based imperatives, competency-based learning, and value-based education can the existing problems of a gap between theory and technology, between ideological education and professional knowledge, and between evaluation and educational goals be successfully overcome.

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