

# Exploration on the Teaching Reform of Electrochemical Experiment Courses in Universities under the Background of Emerging Engineering Education

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**Abstract:** With the deepening of the new round of scientific and technological revolution and industrial transformation, as well as the advancement of the “dual carbon” strategy, higher requirements have been put forward for the innovative, practical, and interdisciplinary literacy of engineering and technical talents. After the launch of Emerging Engineering Education, experimental teaching reform has become the core link in the transformation of engineering education paradigm. As a municipal key university specializing in engineering, the University of Shanghai for Science and Technology (USST) has a development orientation in line with the requirements of Emerging Engineering Education and has carried out comprehensive teaching reforms. The Institute of Energy Materials Science has also introduced cutting-edge electrochemical projects into undergraduate experiments, but a systematic new system of electrochemical experiment teaching has not yet been formed. Taking the electrochemical experiment teaching of USST as the research object, this paper analyzes the common bottlenecks and personalized needs of experimental teaching under the background of Emerging Engineering Education, and explores the construction of a comprehensive reform plan of “value guidance, ability orientation, digital empowerment, and industry-education collaboration.” Centered on the systematic reconstruction of teaching content, the reform links five aspects: teaching mode, digital platform, diversified evaluation, and industry-education collaboration mechanism. It aims to promote the transformation of experimental teaching from a verification link to a core position for ability training, cultivate outstanding engineering and technological talents adapting to industrial needs, and provide a referable demonstration paradigm for practical teaching reform in similar local engineering universities.

**Keywords:** Emerging Engineering Education; Electrochemical experiment courses; Teaching reform; Digital empowerment; Industry-education collaboration; Practical teaching

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## 1. Introduction

With the continuous deepening of the new round of scientific and technological revolution and industrial transformation, strategic emerging industries represented by new energy and new materials are booming, which puts higher and more urgent requirements on the innovative thinking, practical ability, and interdisciplinary literacy of engineering and technical talents. To actively respond to this challenge, the Ministry of Education of China launched the construction of Emerging Engineering Education in 2017, aiming to promote the transformation of engineering education paradigm from adapting to industries to leading industries<sup>[1,2]</sup>. In this context, as a key bridge connecting theoretical knowledge and engineering practice, the in-depth reform of experimental teaching has become the core link for the successful implementation of Emerging Engineering Education.

As a municipal key university rooted in Shanghai and specializing in engineering, USST's development orientation is highly consistent with the requirement of "actively serving local economic and social development and meeting enterprise technological innovation needs" emphasized in Emerging Engineering Education. In recent years, the university has launched a comprehensive teaching reform centered on talent training, clearly proposing to break the traditional training inertia, break the barriers of industry-education integration, and dynamically adjust major settings to serve the development of biomedicine, advanced power and new energy, advanced manufacturing, high-end equipment, artificial intelligence, urban governance and other industries<sup>[3,4]</sup>, aiming to inject talent vitality into the high-quality development of the Yangtze River Delta and even the whole country. Under the grand narrative of energy transition and the "dual carbon" strategy, electrochemical technology, as the scientific foundation of key fields such as energy storage, hydrogen energy, and high-end manufacturing, has become increasingly important in talent training. The Institute of Energy Materials Science of USST has made beneficial attempts in teaching reform. For example, cutting-edge material preparation and performance testing projects of solid-state batteries and aqueous batteries have been introduced into undergraduate electrochemical experiments, integrating the concept of green energy and hands-on practice<sup>[5]</sup>. However, how to systematically upgrade such sporadic cutting-edge projects into a sustainable and promotable new system of electrochemical experiment teaching meeting the requirements of Emerging Engineering Education is still a core proposition to be solved urgently in the current reform.

Taking the electrochemical experiment teaching of USST as the specific object, this paper aims to deeply analyze the common bottlenecks and personalized needs of experimental teaching under the background of Emerging Engineering Education, and explore the construction of a comprehensive reform plan of "value guidance, ability orientation, digital empowerment, and industry-education collaboration." Its significance lies not only in improving the quality of talent training for relevant majors in the university, but also in providing a referable and operable practical paradigm for similar local engineering universities to respond to the urgent demand of the era for innovative outstanding engineering talents.

## 2. Analysis of current situation and existing problems of practical teaching

The higher engineering education circles at home and abroad have generally recognized the limitations of traditional experimental teaching and carried out diversified reform practices under the guidance of Emerging Engineering Education, mainly focusing on two directions.

First, the teaching objectives and content have shifted from “skill verification” to “innovation empowerment,” constructing a stepped and challenging experimental curriculum system. For example, the Demonstration Center of the School of Chemistry and Chemical Engineering, Shanxi University has built a three-level progressive system of “basic-comprehensive-innovative,” raising the proportion of comprehensive and design experiments to more than 40%, implementing “research feeding teaching,” and allowing students to face real scientific problems in the industry. USST has offered “College Students’ Innovation and Entrepreneurship Project Courses”<sup>[6]</sup>, encouraging students to participate in the whole process of projects across disciplines. Cutting-edge technologies such as in-situ characterization, high-throughput calculation, and artificial intelligence-assisted material design have also been introduced into electrochemical teaching to enhance the cutting-edge nature of teaching.

Second, new forms of “virtual-real combination, integration of theory and practice” have been explored in teaching modes and methods, using virtual simulation to solve the problems of expensive equipment, complex operation, high safety risks, and difficult observation of microscopic processes in electrochemical experiments. Virtual experiment platforms related to new energy batteries and simulation teaching projects of large-scale analytical instruments have been built in China. Minzu University of China adopted the mode of “virtual-real combination, internal and external dual access” in the experiment of “Lithium-ion Battery Design and Production,” conducting virtual simulation design optimization and safety rehearsal first, and then physical experiment verification and production, which significantly improved teaching efficiency and depth.

However, compared with the requirements of “interdisciplinary integration and industry-education collaboration” in Emerging Engineering Education, electrochemical experiment teaching in local universities still has obvious shortcomings: first, the experimental system is scattered, industry-education integration is not deep, projects lack full-chain design, disconnected from industrial research and development, and students’ engineering application cognition is not systematic; second, practical innovation training is weak, experimental courses account for a low proportion of credits and are highly dependent, making it difficult to form an independent and systematic ability training; third, the evaluation method is single, focusing on reports and operation specifications, with insufficient assessment of experimental design and problem troubleshooting, which is difficult to support the cultivation of core literacy in Emerging Engineering Education.

Guided by the education philosophy of “student-centered and serving local industrial development”<sup>[7]</sup>, USST closely aligns with the overall goal of cultivating innovative talents serving regional economic development. Relying on the existing innovative and practical teaching of new batteries and interdisciplinary scientific research project courses at the university level in the Institute of Energy Materials Science, USST fully absorbs the mature experience of domestic universities in experimental system reconstruction and virtual-real integration teaching<sup>[8]</sup>, and deeply connects with the actual demand for electrochemical talents in regional advantageous industries such as Shanghai new energy vehicles and hydrogen energy, striving to build a new electrochemical experiment teaching ecosystem led by comprehensive design projects, supported by modern on-campus laboratories, and guaranteed by a multi-collaboration mechanism. The research focuses on building an open and hierarchical progressive experimental project system, forming a hybrid teaching mode running through pre-class, in-class and after-class, establishing a diversified evaluation system taking into account process and result, ability and literacy, and exploring a sustainable path of “university-

enterprise-university-institute” collaborative education, so that experimental teaching can play a core role in strengthening students’ engineering practice ability, innovative thinking and professional literacy, providing a systematic and promotable practical paradigm for the cultivation of high-quality electrochemical talents.

### **3. Main contents and measures of electrochemical experiment course reform under the background of Emerging Engineering Education**

Driven by the dual forces of Emerging Engineering Education construction and regional industrial upgrading, the reform of electrochemical experiment courses needs to go beyond the single teaching of instrument operation and basic theories, and turn to the systematic cultivation of students’ ability to solve complex engineering problems, interdisciplinary innovative thinking, and modern scientific research literacy<sup>[9]</sup>. Taking electrochemical practical teaching as an example, this paper suggests that the reform should focus on five core dimensions: system reconstruction, model innovation, platform support, evaluation reform, and collaborative education, aiming to build a closed-loop, iterative, and continuously evolving new experimental teaching ecosystem.

In terms of the reconstruction of the teaching content system, efforts are made to break the limitations of scattered, single-level, and outdated traditional electrochemical experimental projects, systematically build a three-level progressive and vertically connected ability training chain of “basic-comprehensive-innovative,” and form a modular project library with clear structure, cutting-edge content, and flexible combination<sup>[10]</sup>. The basic consolidation layer takes the optimized classical verification experiments as the core, while retaining key experiments such as cyclic voltammetry and electrochemical impedance spectroscopy, streamlines and reconstructs the experimental content, highlights the training of basic electrochemical principles, data acquisition logic and standardized operation, and introduces virtual simulation pre-experiments and safety access mechanisms, so that students can complete instrument parameter setting, process rehearsal and risk identification before entering the physical laboratory, effectively improving the efficiency, standardization and safety of experimental teaching.

In terms of teaching methods and processes, a hybrid teaching mode of “virtual-real integration, internal and external connectivity” is implemented, building a new paradigm of whole-process practical teaching covering pre-class, in-class, and after-class<sup>[11]</sup>. In the pre-class stage, project task sheets, cutting-edge literature and virtual simulation experimental resources are released through the online teaching platform to guide students to complete knowledge preview and safety assessment, and repeatedly rehearse experimental processes, freely adjust parameters, observe microscopic reaction mechanisms, and even simulate wrong operations and their consequences in the virtual experimental environment, so as to form a relatively mature and personalized experimental plan before entering the physical experiment; in the in-class stage, the core time of physical experimental courses is used for scheme discussion, key operation skill strengthening, in-depth observation of experimental phenomena and immediate problem solving. Teachers change from traditional operation demonstrators to project guides and learning facilitators, helping students cope with uncertainties in real experiments through team collaboration and situation guidance, and realize real-time collection, sharing, and preliminary analysis of experimental data with the help of mobile intelligent experimental terminals.

In terms of digital support, efforts are made to build an intelligent experimental teaching platform integrating “physical-virtual.” First, develop deeply interactive virtual simulation resources, break through

the limitations of instrument demonstration, build experimental projects revealing the correlation between micro and macro (such as digital twin battery simulation), support dynamic parameter adjustment and intuitive performance presentation, and introduce AI-assisted design modules to generate optimized schemes. Second, build an intelligent laboratory management platform integrating appointment, consumables, data collection, storage, and safety monitoring, establish a standardized database and case library, support data comparative analysis, and present results through a digital experimental wall, creating a data-driven and open-shared teaching environment <sup>[12]</sup>.

In terms of the reform of the assessment and evaluation system, focusing on the overall improvement of students' practical ability and comprehensive literacy, a diversified evaluation model of "equal emphasis on process and result, parallel ability and literacy" is constructed, with ability achievement as the core orientation, comprehensively and dynamically reflecting students' growth trajectory in experimental learning <sup>[13]</sup>. The evaluation system breaks through the single knowledge assessment in dimension setting, systematically covering professional knowledge application, experimental design and innovation ability, practical operation skills, data analysis and computing tool application, teamwork and communication, achievement report and academic expression, safety and standard awareness, engineering ethics and social responsibility; in terms of evaluation methods, it highlights process and development, comprehensively inspects students' whole process from scheme conception, experiment implementation to achievement summary through diversified evaluation carriers such as experimental scheme design reports, experimental process records and reflection logs, project achievement defense and peer review, and final research reports or papers, and introduces enterprise tutors and interdisciplinary teachers to participate in the evaluation, enhancing the authenticity, professionalism and orientation of assessment, thus effectively guiding students to change from "completing experiments" to "forming abilities and improving literacy."

In terms of deepening industry-education collaboration and faculty development, efforts are made to build a collaborative education mechanism of "two-way empowerment and continuous iteration" to promote the collaborative improvement of teaching content, practical platform, and faculty ability. Through the establishment of a "school-enterprise dual-tutor" system, senior enterprise engineers are introduced as industrial tutors to deeply participate in experimental project design, process guidance, and achievement evaluation. At the same time, on-campus teachers are organized to enter the front line of enterprises to jointly develop case packages and fault libraries around real engineering problems, realizing the effective transformation of engineering experience into teaching resources <sup>[14]</sup>; on this basis, a dynamic update mechanism of teaching content is constructed. The school-enterprise joint teaching steering committee regularly evaluates and iterates the experimental project library, continuously eliminates outdated content and upgrades key projects according to industrial technology development trends and students' learning effects, maintaining the cutting-edge and practical value of the curriculum system <sup>[15]</sup>; at the same time, through the implementation of the teacher engineering ability improvement plan, young teachers are supported to carry out long-term and immersive enterprise practice, and supporting special training such as digital teaching tools and virtual simulation development is carried out, comprehensively improving the engineering literacy and Emerging Engineering Education teaching ability of the teaching team, providing sustainable talent guarantee for high-quality practical teaching.

## 4. Conclusion

The electrochemical experiment course reform of USST is an overall and systematic project led by the systematic reconstruction of teaching content, supported by the collaborative innovation of teaching mode and digital platform, and driven by diversified evaluation and industry-education collaboration mechanism. The fundamental goal of the reform is to break through the traditional positioning of experimental teaching long attached to theoretical teaching, and promote its transformation and upgrading from a “verification teaching link” to a core position for the cultivation of engineering practice and technological innovation ability. Through collaborative efforts in five aspects: teaching content system, teaching methods and processes, digital support platform, assessment and evaluation system, industry-education collaboration and faculty development, the key bottlenecks of insufficient hierarchy, weak engineering orientation, and low digital and industrial integration in experimental courses are gradually solved, and a high-quality practical teaching system oriented to ability achievement is constructed. It is expected that through this reform, students can be systematically cultivated with solid electrochemical foundation, outstanding ability to solve complex engineering problems, proficient literacy in using digital and intelligent tools, and deep understanding of industrial needs, engineering ethics and social responsibility, forming outstanding engineering and technological talents in the new era with innovative awareness and practical ability, providing solid talent support for the construction of Shanghai International Science and Technology Innovation Center and the implementation of the national “dual carbon” strategic goals; at the same time, the concepts and paths formed by this reform can also provide a referable and promotable demonstration paradigm for similar local engineering universities to promote practical teaching reform.

## Disclosure statement

The authors declare no conflict of interest.

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