

Construction of a Virtual Simulation Experimental Platform for Chemical Engineering in Local Universities: A Case Study of Yulin University

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Received: 26 June 2025; Accepted: 17 July 2025; Published: 21 August 2025

Abstract:

With the promotion of “New Engineering” construction, higher requirements have been put forward for the practical and innovative abilities of chemical and chemical engineering professionals. This study takes Yulin University as an example to explore the necessity and feasibility of constructing a virtual simulation experimental teaching platform for chemical and chemical engineering in the background of “New Engineering”. By analyzing the existing problems in experimental teaching, combined with the advantages of virtual simulation technology, this paper describes the construction goals, content, functions, and implementation process of the platform. At the same time, the application effect of the platform was evaluated, and the results show that the platform effectively improved the students’ practical ability and innovative thinking, providing strong support for cultivating chemical and chemical engineering professionals who meet the needs of the new era.

Keywords:

New Engineering, Virtual Simulation, Experimental Teaching, Local Ordinary Bachelor’s Colleges

1. Introduction

The development of ‘Emerging Engineering Education’ (EEE) is China’s core strategy for responding to the technological revolution and industrial transformation, and for promoting innovation in engineering education [1]. It emphasizes interdisciplinary integration, practical innovation, and industry alignment, aiming to cultivate interdisciplinary chemical and chemical engineering talents with international competitiveness. The role of chemical and chemical engineering experimental teaching in EEE: As a crucial component of professional education, chemical and chemical engineering experimental teaching is a key vehicle for cultivating students’ ability to apply theory, practical skills, and innovative thinking. Under the background of EEE construction, chemical and chemical

engineering experimental teaching needs continuous reform and innovation to meet the demands of the new era for cultivating chemical engineering talents [2]. Current Status and Trends in Virtual Simulation Experimental Teaching: Virtual simulation experimental teaching relies on virtual reality, multimedia, and human-computer interaction technologies. By constructing highly simulated experimental environments, it provides students with immersive and repeatable practical platforms [3,4]. Currently, this technology has become an important direction for experimental teaching reform in universities both domestically and internationally [11]. With the continuous advancement of technology, virtual simulation experimental teaching will become more realistic, more interactive, and more fully functional, providing richer teaching resources and more flexible teaching methods for experimental education [5].

As a local undergraduate university, Yulin University faces numerous practical challenges in its experimental teaching, including insufficient hardware facilities, limited funding, outdated teaching content, and weak interdisciplinary integration. There is an urgent need to explore a path for teaching reform suitable for the requirements of EEE. Virtual simulation experimental teaching technology offers new ideas for solving these problems. It can effectively overcome spatiotemporal constraints and reduce experimental costs while enhancing the safety of chemical engineering experimental practice teaching [6,7]. This aligns well with the practical needs of local universities operating with limited resources.

Taking Yulin University, a local undergraduate institution, as an example, this paper systematically analyzes the problems faced in its chemical and chemical engineering experimental teaching, explores the construction goals and implementation pathways for a virtual simulation experimental platform, and assesses its feasibility through practical outcomes. The aim is to provide a reference for practical teaching reform in similar institutions. The following sections will elaborate on the specific problem analysis, platform construction ideas, and practical effects.

2. Current Status and Problem Analysis of Chemical and Chemical Engineering Experimental Teaching at Yulin University

2.1. Experimental Teaching Condition

(1) The equipment and space in Yulin University's chemical and chemical engineering laboratories are relatively limited, making it difficult to meet the growing experimental demands of students. Simultaneously, prolonged usage has led to deteriorating performance of the equipment, and the high maintenance costs further constrain the improvement of teaching quality. (2) The university's financial investment in chemical and chemical engineering experimental teaching is relatively low. This restricts the procurement of experimental materials and reagents and prevents the implementation of some cutting-edge experiments due to resource scarcity, hindering the systematic cultivation of students' practical abilities.

2.2. Experimental Teaching Content

(1) The experimental teaching content at Yulin University primarily consists of traditional verification experiments, lacking comprehensive, design-oriented, and innovative experimental projects. The content is disconnected from actual production and research needs, making it difficult to stimulate students' learning interest and

innovative thinking. (2) There is inadequate integration between chemical/chemical engineering disciplines and other related fields. Experimental projects fail to fully incorporate multidisciplinary knowledge and skills, which is detrimental to cultivating students' comprehensive qualities and cross-disciplinary abilities.

2.3. Experimental Teaching Methods

(1) The traditional lecture-based instruction method is still predominantly used during experimental sessions. Students remain in a passive state of receiving information, lacking opportunities for active thinking and participation. This constrains the cultivation of students' innovative thinking and practical skills. (2) Due to the large number of students, instructors find it challenging to provide comprehensive guidance during experiments. Consequently, some students encounter problems during operations without receiving thorough corrective guidance, preventing them from achieving the expected experimental outcomes and learning gains.

2.4. Experimental Teaching Management

(1) Unreasonable Experiment Scheduling. The arrangement of experimental courses fails to adequately consider the characteristics of the disciplines and the competency progression of students. Issues such as content repetition and scheduling conflicts exist, leading to insufficient teaching coherence. (2) Imperfect Quality Monitoring System. The university's monitoring of experimental teaching quality primarily relies on lab reports and exam scores. There is a lack of effective monitoring and evaluation of the experimental process itself, making it difficult to comprehensively and objectively reflect students' practical proficiency and learning outcomes.

Finally, the chemical and chemical engineering experimental teaching at Yulin University is constrained by practical issues such as resource shortages, outdated content, and monotonous methods. This makes it challenging to meet the high demands of "Emerging Engineering Education" (EEE) for practical innovation capabilities. Against this backdrop, virtual simulation experimental teaching technology, capitalizing on its distinctive advantages, offers a new approach for reforming traditional experimental teaching.

3. Advantages and Significance of the Virtual Simulation Experimental Teaching Platform

3.1. Advantages of the Virtual Simulation Experimental Teaching Platform

(1) Breaks Spatiotemporal Barriers. The platform eliminates constraints of time and space, allowing students to access and conduct experimental learning anytime and anywhere via the internet. This enhances learning flexibility and autonomy. (2) Reduces Experimental Costs. Virtual experiments consume no physical consumables and are repeatable, effectively minimizing the waste of teaching resources. (3) Mitigates Safety Risks. Certain chemical and chemical engineering experiments involve hazards such as flammability, explosiveness, toxicity, or harm. Virtual simulations enable students to perform hazardous experiments in a virtual environment, effectively circumventing safety risks associated with physical operations. (4) Expands the Breadth of Teaching Content. The platform offers diverse experimental projects, including simulations of traditional experiments, design of

comprehensive experiments, and the translation of cutting-edge research findings. Students can select projects based on their interests and needs, broadening their knowledge base and perspectives. (5) Strengthens Practical Competence and Innovative Thinking. The platform provides an environment for independent exploration and innovative practice. Students can freely design experimental procedures, operate virtual equipment, observe phenomena, and analyze data, cultivating practical skills and innovative mindsets.

3.2. Significance of Building the Virtual Simulation Experimental Teaching Platform

(1) Aligns with EEE Talent Cultivation Goals. Through multimodal resource integration and a hybrid teaching model combining virtual and physical elements, the platform supports the synergistic development of students' practical abilities and interdisciplinary literacy, precisely meeting the educational objectives of EEE. (2) Drives Iterative Upgrading of Experimental Teaching. The construction of the platform represents a critical direction for reforming chemical and chemical engineering experimental teaching. Integrating virtual simulation technology with experimental instruction can overcome the limitations of traditional methods, innovate teaching models and approaches, enhance teaching quality and effectiveness, and propel the reform and development of experimental education. (3) Elevates Institutional Competitiveness. The platform enhances the institution's teaching resource capacity and informatization level, thereby improving overall teaching quality and educational standards. Simultaneously, it provides support for scientific research, fostering discipline development and institutional advancement.

The alignment between the specific functions of the virtual teaching platform and the requirements of Emerging Engineering Education (EEE) charts a clear path for experimental teaching reform at Yulin University. Building upon this insight and rooted in practical needs, we propose concrete construction objectives for the Chemical and Chemical Engineering Virtual Simulation Experimental Teaching Platform. These objectives aim to achieve comprehensive enhancement of teaching quality through resource integration and system optimization.

4. Construction Objectives of the Chemical and Chemical Engineering Virtual Simulation Experimental Teaching Platform at Yulin University

Build an advanced, practical, and open-access virtual simulation platform for chemical and chemical engineering experiments. Integrate the university's existing experimental teaching resources to achieve resource sharing. Develop a series of representative, innovative, and practical virtual simulation experiment projects, covering multiple levels and domains such as: basic chemistry experiments, chemical engineering principles experiments, and professional comprehensive experiments. Establish a dynamic management system encompassing "planning-implementation-assessment" across the entire teaching workflow, focusing on course arrangement, process monitoring, and evaluation feedback to ensure standardized operation of experimental teaching. Cultivate a high-caliber teaching faculty proficient in virtual simulation experimental instruction, enhancing instructors' pedagogical capabilities and digital literacy. Improve students' practical competence, innovative thinking, and comprehensive qualities, fostering chemical and chemical engineering professionals equipped to meet the demands of the new era.

However, newly created things inevitably have imperfections. Translating these platform objectives into concrete practices becomes crucial. To further realize the three core goals—teaching resource integration, pedagogical innovation, and student competency development—the functional design of the virtual simulation platform must be objective-oriented, supporting the entire teaching process through modular architecture design.

5. Functions of Yulin University's Chemical and Chemical Engineering Virtual Simulation Experimental Teaching Platform

5.1. Experimental Teaching Management System

(1) Teachers design experimental teaching plans via the system, scheduling course times, venues, and instructors. Students access their personal schedules for preparatory work. (2) The system integrates student profiles, learning trajectories, and experimental data to generate visualized learning portfolios, enabling personalized instruction. (3) Teachers evaluate and record student performance post-experiment. Students self-monitor results through the system.

5.2. Virtual Experiment Operation Module

(1) Leveraging VR and 3D modeling, the module recreates realistic lab environments—including layouts, equipment exteriors, and internal structures—allowing free navigation via mouse/keyboard. (2) Human-computer interaction and sensor technologies simulate instrument manipulation (power on/off, calibration). Students observe operational states and experimental phenomena. (3) Students set parameters (temperature, pressure, flow rate). The system simulates experiments in real-time based on inputs, enabling iterative optimization of experimental designs to cultivate innovation.

5.3. Experimental Assessment System

(1) Timed assessments on experimental principles, methods, and data processing evaluate theoretical mastery. (2) The system scores students' procedural compliance, technical fluency, and result accuracy against predefined rubrics during simulations. (3) Integrates theory tests, skill ratings, and innovative solution designs into competency radar charts, holistically mapping practical literacy and cognitive potential.

6. Implementation of the Chemical and Chemical Engineering Virtual Simulation Experimental Teaching Platform at Yulin University

The university has established a Platform Construction Steering Committee composed of university leadership, heads of relevant functional departments, and directors of the School of Chemical Engineering. This committee oversees strategic planning, coordination, and guidance for platform development. Concurrently, a Specialized Task Force comprising full-time faculty and technical experts has been formed to execute concrete implementation.

Based on comprehensive needs assessment and feasibility studies, the university has formulated a development blueprint and implementation plan for the platform. To address cross-departmental collaboration requirements, a Responsibility

Matrix clearly defines all stakeholders' roles, ensuring clarity of duties and seamless coordination during multi-departmental advancement.

Upon completion of virtual simulation experiment development, these projects are integrated into the experimental teaching curriculum to establish a hybrid virtual-physical teaching model. During implementation, feedback from instructors and students is systematically collected to continuously refine content and functionality. Through iterative improvements, the quality and effectiveness of virtual simulation teaching are enhanced.

A blended online-offline instructional approach positions virtual simulations as supplements and extensions to traditional experiments, elevating overall teaching outcomes. Additionally, virtual simulation competitions and dynamic assessment mechanisms stimulate student engagement, ensuring tangible educational reform results.

7. Application Evaluation of the Virtual Simulation Experimental Teaching Platform at Yulin University

A comparative analysis of multi-dimensional data reveals that students supported by the platform demonstrate significant improvements in academic performance and practical capabilities. Marked leaps are observed in: mastery of experimental theory, proficiency in operational skills, and competence in data processing and analysis.

Faculty widely acknowledge the platform's role in enhancing pedagogical efficiency, enriching teaching content and methods. The repeatability and visualization features of virtual experiments enable clearer explanation of principles and procedures. Pre-/post-implementation teaching quality metrics confirm substantial enhancement. Instructors more effectively guide experimental inquiry, fostering students' innovation capacity.

8. Conclusions and Outlook

This study, using Yulin University as a case, explores the construction of a virtual simulation experimental teaching platform for chemical and chemical engineering within the context of Emerging Engineering Education (EEE). Through an analysis of the current state of experimental teaching, we established the necessity and urgency of developing such a platform

With the continuous development of information technology and the advancement of the "new engineering" construction, the virtual simulation experiment teaching platform for chemistry and chemical engineering will be constantly improved and developed. In the future, the virtual and real integration teaching mode will be further strengthened and deepened to enhance students' practical hands-on ability and innovation ability. Promote the inter-school collaborative sharing mechanism to enhance the utilization efficiency of resources and social benefits; Strengthen the intelligent construction of the virtual simulation experimental teaching platform to improve the efficiency and level of teaching management. It is believed that with the joint efforts of all parties, the virtual simulation experiment teaching platform for chemistry and chemical engineering will play a more important role in cultivating high-quality professionals in chemistry and chemical engineering.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding

The completion of this thesis was supported by the following educational reform projects: Shaanxi Province “Sanqin Talent” Program Project (2024-RCGC-03), Undergraduate Teaching Reform Research Project of Yulin University (JG2423), and Undergraduate Teaching Team Project of Yulin University (JXTD2401).

References

- [1] Miranda, J.; Navarrete, C.; Noguez, J.; Molina-Espinosa, J.M.; Ramírez-Montoya, M.S.; Navarro-Tuch, S.A.; Bustamante-Bello, M.R.; Rosas-Fernández, J.B.; Molina, A. The core components of education 4.0 in higher education: Three case studies in engineering education. *Computers & Electrical Engineering*, 2021, 93, 107278. DOI.org/10.1016/j.compeleceng.2021.107278.
- [2] Wang, X.; Xu, L.; Gong, L. Innovative Research and Practice of Training Mode for Applied Chemistry Talents under the Background of Emerging Engineering Education: Taking Applied Chemistry Major of Qingdao Agricultural University as an Example. *University Chemistry*, 2020, 235(10), 92-98. DOI: 10.3866/PKU.DXHX202006014.
- [3] Zhang, Ji.; Zhang, Z.; Jin, X.; Wang, Y.; Han, D.; Li, J. Research and Practice on Construction of First-Class Major in Local Engineering Colleges. *University Chemistry*, 2023, 38(5), 1-5. DOI: 10.3866/PKU.DXHX202206034.
- [4] Li, Y.; Zhang, F.; Zhang, T.; Han, L.; Sun, X.; Zhang, X.; Zhu, W.; Cai, J.; Li, C.; Sun, X. Exploration and Practice of Cultivating Innovative Talents in Pharmaceutical Specialty Based on Deep Integration of Industry–University–Research. *Journal of Chemical Education*, 2024, 101(8), 3126-3134. DOI: org/10.1021/acs.jchemed.3c01334.
- [5] Yan, Q.; Li, L.; Chen, M.; Gu, X. Research on the Sustainable Improvement Mechanism of the Chemical Engineering and Technology Major Based on the Concepts of Outcome-Based Education–Plan-Do-Check-Act (OBE–PDCA) in Engineering Education. *Sustainability*, 2025, 17(9), 4051. DOI.org/10.3390/su17094051.
- [6] Li, Y.W.; Zhang, H.F.; Zhang, T.Y.; Han, L.; Sun, X.L.; Zhang, X.M.; Zhu, W.H.; Cai, J.H.; Li, C.; Sun, X. Exploration and Practice of Cultivating Innovative Talents in Pharmaceutical Specialty Based on Deep Integration of Industry–University–Research. *Journal of Chemical Education*, 2024, 101(8), 3126-3134. DOI: org/10.1021/acs.jchemed.3c01334.
- [7] Neves, R.M.; Lima, R.M.; Mesquita, D. Teacher Competences for Active Learning in Engineering Education. *Sustainability*, 2021, 13(16), 9231. DOI: org/10.3390/su13169231.



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