

AI-Empowered Virtual Screening-Driven Innovation and Practice of Virtual – Real Integrated Classroom Teaching in Medicinal Chemistry

Shuangcheng Zhi*, Meidie Cheng, Jingyi Sang, Wei Xu, Yiru Yang, Xiaoyue Peng, Can Xu, Bingbing Li, Yanxin Ye

Henan University of Urban Construction, Pingdingshan, 467036, China

*Corresponding author: zhisc@huuc.edu.cn

Abstract: In order to solve the pain points of the traditional “Medicinal Chemistry” classroom such as focusing only on theory without practice, lack of applications of AI and virtual screening tools, and disconnecting teaching content from regional industry needs, we, under support of the “Emerging Engineering Education”, “Artificial Intelligence Plus” action plans, proposed an integrated virtual – real innovative teaching model based on AI-based druggability prediction, virtual screening and teaching-session design; then conducted teaching with the practical case of molecular docking of hexahydrocurcumin with heat shock protein 90 α (HSP90 α), which is included in the chapter about natural antitumor drugs. The model realized two-way empowerment between the virtual and the physical – the average time students spend using AutoDock Vina was decreased by 32%, 92.4% of students reported that their learning interest has been significantly increased, the experimental group significantly outperformed the control group in connecting molecular docking with experimental design, and provides a replicable paradigm for cultivating pharmaceutical talents at local application-oriented undergraduate institutions.

Keywords: Artificial Intelligence; Molecular Docking; Virtual – Real Integration; “Medicinal Chemistry”

Introduction

“Medicinal Chemistry”. Wide knowledge scopes, abstract structures and strong practicability. With the advancement of “Emerging Engineering Education”, “Artificial Intelligence Plus”, the demand of pharmaceutical industry changes from experimental operation towards composite talent in computational drug design^[1]; Traditional teaching has three major pain points: First, emphasis on theory. Drug synthesis experiment is full of high risk reagents with high cost, there are few chances for students' hands-on experience, most classroom teaching emphasizes on theoretical instruction and demonstration^[2]; secondly, superficial application of AI. Some universities introduce tools like AutoDock Vina but just show how to operate it instead of deeply integrating AI to optimize drug screening; Thirdly, disconnects between industry and education. Most teaching cases focus on general targets ignore regional prevalent diseases leading to a misalignment between talent cultivation and real needs of local industry^[3].

The biomedical industry in Henan has their own characteristics (e.g., Hualan Biological focuses on vaccines; Genuine Biotech is deeply involved in antiviral drugs), but traditional teaching just stresses the structure-activity relationships for classical drugs without touching frontier fields like innovative drugs which are desperately needed by enterprises. The existing industry education integration suffers from the dilemma of “the schools' enthusiasm and the enterprises' coldness”^[4]—universities don't connect with local enterprise R&D projects or turn enterprise data into teaching resources leading to the triple disconnection between teaching content, industry needs and students' abilities. We explore systematically embedding artificial intelligence drug discovery (AIDD) technology into all the teaching processes of “Medicinal Chemistry”^[5], establishing a virtual–real integrated teaching model based on regional disease targets, bridged by virtual screening and founded upon rational experimental design.

1. Design and Implementation of the Teaching Model

Our model's three related modules: AI based druggability prediction module, virtual screening

practice module and teaching session design module (Figure 1), is a teaching closed loop which includes theoretical foundations, practical abilities and innovative literacy promoting progressive learning from theory to practice. We use AIDD technology as forerunner, regional high-incidence disease targets as orientation, real R&D needs of local enterprises as driver, virtual screening as bridge and physical experiments as foundation to build up a teaching closed loop with virtual containing the real and the real containing the virtual^[6].

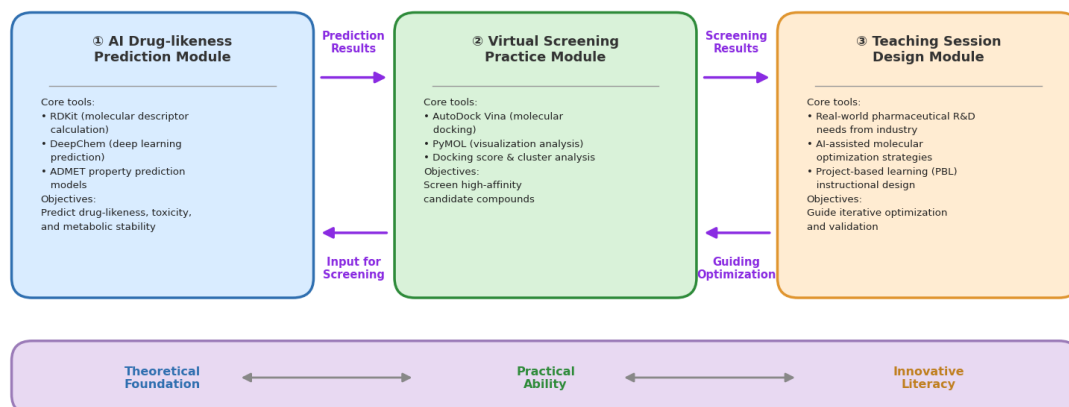


Figure 1 Core Framework of This Model

The model adheres to the OBE philosophy: going from teacher-centered to student-centered; adopting a backward design strategy^[7]—we begin theoretical teaching with natural antitumor drugs and then introduce the HSP90 α target whose N-terminal ATPase domain is an important target for antitumor drug design^[8], guiding our students to use SWISS-MODEL to predict the three-dimensional structure of HSP90 α , comparing and verifying prediction according to the PDB crystal structure (3INW), GMQE=0.87 which indicates very reliable predicted model (Figure 2).

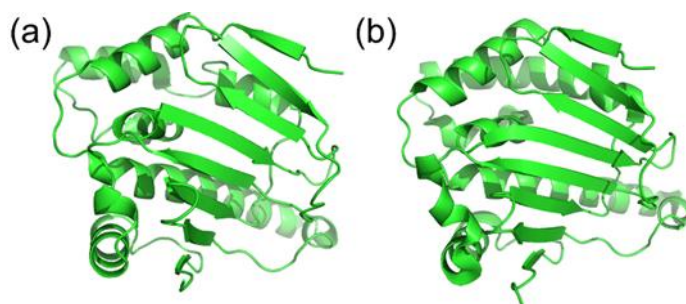


Figure 2 (a) SWISS-MODEL-predicted three-dimensional structure of the full-length HSP90 α protein and (b) its resolved crystal structure

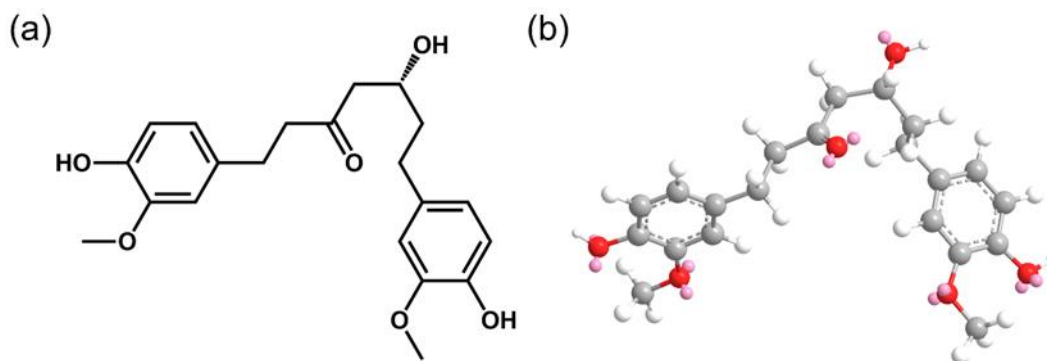


Figure 3 Energy-minimized conformation of hexahydrocurcumin

Meanwhile, by applying a molecular docking system with hexahydrocurcumin as the ligand molecule (Figure 3), students get its structure through PubChem and use RDKit to calculate the Lipinski's Rule of Five parameters (Table 1) that assesses its druggability^[9] and it fully complies with the rules and has

great potential for oral bioavailability. By employing open-source AI frameworks such as DeepChem, students are able to predict ADMET properties shifting their thinking from empirical judgement towards data-driven reasoning.

Table 1 Lipinski's Rule of Five Parameters and Druggability Assessment of Hexahydrocurcumin

Parameter	Value	Lipinski's Rule of Five Parameters	Druggability Assessment
Molecular Weight/Da	390.43	< 500	Pass
LogP	3.52	< 5	Pass
Number of Hydrogen Bond Donors	3	≤ 5	Pass
Number of Hydrogen Bond Acceptors	7	≤ 10	Pass

During our virtual practice session, Virtual – real integrated progressive training: Students use AutoDock Tools to process the receptor protein (remove water, add hydrogen, assign charges, etc)^[10], by AutoDock Vina to do docking; we introduce the deep learning based docking tools for parallel comparisons^[11]; students utilize tools like PyMOL to visualize their result (Figure 4); it showed that hexahydrocurcumin has a good binding potential with the binding pocket of HSP90 α (the binding energy of the best conformation is -7.99 kcal/mol). The two dimensional interaction diagram is utilized to quantify contribution from each interaction and build structure activity relationship.

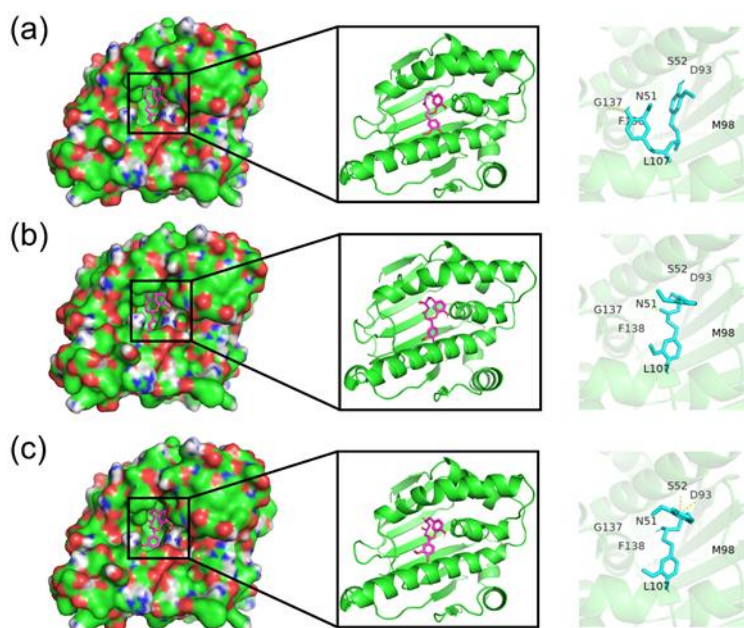


Figure 4 Molecular docking results of hexahydrocurcumin with the HSP90 α ATPase binding pocket.

Teaching Design Session: Using generative AI tools like REINVENT v4.0, students conduct scaffold hopping/side chain modification on hexahydrocurcumin (e.g., replace the methoxy group with a nitrogen-containing basic group, or scaffold hop its terminal aromatic ring to a heteroaromatic ring such as pyridine), breaking through the chemical space limit of the original molecule but keeping important pharmacophores, achieving multi-parameter druggability optimization; then new compounds will be screened by batch docking forming an effective closed loop^[12]; Experimental Validation Session: Lead the process of conducting Pearson correlation analysis between the real activity data from the literature and predicted binding energy based on real data to validate the accuracy of the model, thus establishing the rigorous logical thinking of scientific research: "The computational prediction is the starting point, and the experimental validation is the endpoint". We established a dual mentor system with enterprises

such as Henan Genuine Biotech^[13] that transform de-identified data into teaching cases. The case library mainly includes targets such as HSP90 α and EGFR in regional high-incidence tumors such as lung cancer and gastric cancer. After review by enterprise mentors, students' virtual screening report can become the basis for their graduation project, which smoothly links up the course and professional practice.

2. Evaluation of Teaching Effectiveness and Analysis of Outcomes

A diversified assessment system including formative as well as summative assessments was proposed by us^[14]. The summative assessment is a mixture between theory exam and virtual simulation practical operations; for practical operation, we used an automatic scoring combining binding energy prediction accuracy and completeness of interaction analysis for students (Table 2).

Table 2 Indicator Points of the Diversified Assessment System

Evaluation Dimension	Weight	Assessment Content
Proficiency in Using AI Tools	20%	PDBQT conversion and parameter setting (5%); docking box setup (5%); result interpretation and problem diagnosis (10%)
Project Report Quality	20%	Scientific quality and visualization presentation of molecular docking results
Team Collaboration and Performance	20%	Innovation capability in interdisciplinary group proposals for AI-assisted drug design competitions
Summative Assessment	40%	Theoretical part and practical operation part

In comparison with traditional teaching, under this model: (i) The average operation time of AutoDock Vina decreased by 32%, all students could independently complete the whole SWISS-MODEL workflow; (ii) The performance of the experimental group is better than the control group for designing in vitro validation experiments according to screening results or skill evaluation. According to our questionnaire survey, 92.4% of the students believe that their learning interest has greatly increased, and 89.5% have a concrete understanding of AIDD technology. Based on students' suggestions to improve computing power, adding more enterprise data and including molecular dynamics simulations, we started building a dedicated cloud computing platform and added an advanced molecular dynamics joint practical training.

Discussion

The key innovation is our deep embedding of AIDD technology throughout the whole teaching process, which breaks out from superficial demonstrations^[15], enabling students to master software operations as well as understand model principles and applicable scenarios via a closed loop of AI prediction, screening and design; the virtual – real integrated model solves the issues of high cost and high risk for traditional experiments and optimizes allocation of teaching resources^[16]; meanwhile, via the dual-mentor system and introduction of de-identified enterprise data, it can effectively satisfy the need of local industries while avoiding homogenized teaching based on general targets.

Our model encourages composite talents able to achieve virtual – real integration through popularization of using AI tools for all students without homogenous teaching according to general targets and virtual databases meeting enterprise needs^[17, 18] but there are some shortcomings in our study: First, AI technology iterates fast whereas course practice lags behind; Second, it has an insufficiency about covering interdisciplinary knowledge which we plan to add cross-course modules (e.g., AI-assisted druggability optimization) etc.; Thirdly, scoring functions have limitations. The teaching team attempts to introduce AI teaching assistants helping guiding parameters and diagnosing errors, integrate regional characteristic target resources, extend case library testing the universality of the model, cooperate with enterprises establish a job competency evaluation system in the future.

Conclusion

The successful implementation of an integrated teaching model that combines AI-based druggability prediction, virtual screening, and teaching design can improve students' computational drug design

ability and aligns with regional industry: This provides a new paradigm for teaching reform to cultivate pharmaceutical talents at local application-oriented undergraduate institutions. As generative AI advances, balancing the cutting-edge nature of technology with teaching principles and deepening the long-term mechanism of industry-education integration are worthy of further exploration.

Fund Projects

- Henan Provincial Joint Fund for Science and Technology Tackling Key Problems (252103810298);
- Higher Education Teaching Reform Research and Practice Project of Henan University of Urban Construction (2026JG098);
- Applied Undergraduate Course of Henan University of Urban Construction (Xiaozhengjiao [2025] No. 234);
- Industry-University-Research Cooperation Project of Henan University of Urban Construction (K-H2025108);
- Science and Education Integration Project of Henan University of Urban Construction (K-X2026182);
- Scientific Research Startup Fund of Henan University of Urban Construction (K-Q2025010).

References

- [1] Zhou Zhan, Cao Ji, Zhou Binbin, et al. Exploration and Practice of Artificial Intelligence-Empowered Reform in Pharmaceutical Education. *Pharmaceutical Education*, 2025, 41(4): 1-6.
- [2] Han Xinya, Chen Yiliang. Exploration of "Three-Step" Teaching Practice in the Medicinal Chemistry Course for the Chemical Biology Major. *Journal of Anhui University of Technology (Social Sciences Edition)*, 2025, 42(4): 35.
- [3] Wang Cunqin, Nian Sihui, Zhang Yanhua, et al. Exploration and Practice of AI-Empowered Teaching in "Natural Medicinal Chemistry". *Journal of Tonghua Normal University*, 2025, 46(10): 115-122.
- [4] Wang Guoqiang, Li Qian, Wu Zhongcheng. Exploration and Practice of Teaching Reform in Advanced Mathematics Courses at Local Engineering Universities from the Perspective of Industry-Education Integration. *Creative Education Studies*, 2024, 12(6): 462-471.
- [5] Zhang Yali. Practical Exploration of Teaching Reform in the Food Medicinal Chemistry Course Based on the OBE Philosophy. *China Food Industry*, 2025(4): 157-159.
- [6] Huang Jin, Xu Zhongyu, Yue Lingjia. Design of Experimental Teaching Cases for Medicinal Chemical Biology Based on the OBE Philosophy. *Laboratory Research and Exploration*, 2020, 39(5): 1-5.
- [7] Zhou Wei, He Miao, Ren Xiaoming, et al. Construction and Practice of Student Independent Innovation Experimental Bases Based on the OBE Philosophy. *Laboratory Research and Exploration*, 2023, 42(12): 247-251.
- [8] ABOALROUB A A. Virtual screening and molecular docking characterization of Isoxazole-based molecules as potential Hsp90 inhibitors: In silico insight. *Medinformatics*, 2024, 2(3): 154-166.
- [9] KURMI S P C, THAPA S, KARATI D. Molecular docking and pharmacokinetic evaluations of curcumin-based scaffolds as MDM2-p53 inhibitors. *Discover Chemistry*, 2025, 2(1): 53.
- [10] MUHAMMED M T, AKI-YALCIN E. Molecular docking: principles, advances, and its applications in drug discovery. *Letters in Drug Design & Discovery*, 2024, 21(3): 480-495.
- [11] BUCCHERI R, RESCIFINA A. High-Throughput, High-Quality: benchmarking GNINA and AutoDock VINA for precision virtual screening workflow. *Molecules*, 2025, 30(16): 3361.
- [12] Wang Gailing, Tao Zhijie, Sun Xiaoxia, et al. Teaching Reform of the Bio-Pharmaceutical Major Based on the CDIO Philosophy. *College and Job*, 2025, 14: 145220.
- [13] Pan Deng, Zhang Wanxin, Song Yunzhi. Exploration of Artificial Intelligence-Empowered "Theory-Practice Integration" Teaching Reform in the Pharmaceutical Preparation Technology Course. *Education and Teaching Methods*, 2025(6): 15-20.
- [14] Jiao Lei, Zhang Yang, Li Jiamin, et al. Exploration of Artificial Intelligence-Empowered Teaching Reform in Pharmacology. *Pharmaceutical Education*, 2025, 41(3): 76-79.
- [15] Shen Shoumao, Li Yan, Zhou Kang, et al. Exploration of an AI-Integration Innovation-Driven Talent Cultivation Model for Top Pharmaceutical Classes: Taking Natural Medicinal Chemistry Teaching as an Example. *Modern Vocational Education*, 2026(12): 72-75.

[16] Yang Yifan, Wang Yuji, Jiang Xueyun, et al. Practice and Exploration of the National-Level Blended First-Class Course "Pharmaceutical Professional Skills Experiment". *Continuing Medical Education*, 2025, 39(6): 108-111.