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Original Article

Design and Application of the Blended Teaching Mode in the Curriculum of Pharmacokinetics

Zhongbing Liu[1,#], Shuzao Wang[1,#], Yan Lin[1], Meiling Zhou[2], Pei Jing[2,*], Zhirong Zhong[1,*]

[1]Department of Pharmaceutical Sciences, School of Pharmacy, Southwest Medical University, Luzhou, Sichuan, CHINA.
[2]Department of Pharmacy, The Affiliated Hospital of Southwest Medical University, Luzhou, Sichuan, CHINA.
[#]These authors contributed equally to this work.

ABSTRACT

Introduction: Pharmacokinetics is one of the main courses of pharmacy majors in medical colleges and universities. The course is highly practical involving multidisciplinary collaboration, with strong logical reasoning and complex calculations. But the widespread traditional teaching methods resulted in poor practical application ability, self-learning ability, and problem-solving ability of students. **Objectives:** To enhance the students' knowledge and problem-solving ability, we focused on the curriculum reform of pharmacokinetics. **Materials and Methods:** It was based on the online and offline mixed teaching mode including revising the training program and syllabus, reconstructing the teaching staff, constructing online courses, designing class teaching, and careful teaching implementation, and construction of evaluation system. Finally, questionnaire survey was conducted to evaluate the implementation effect about the "online + offline" hybrid teaching mode. **Results:** It showed that the mixed online and offline teaching mode can help to solve the problem of difficulty in both teaching and learning the pharmacodynamics course. It changed the students' rigid learning methods that are not conducive to the cultivation of applied high-quality pharmaceutical talents. Moreover, this teaching reform enhanced the students' problem-solving ability. It achieved the course goals of cultivating students to be competent in medication guidance, drug quality control, and supervision positions, and to have the basic ideas and abilities to innovatively research and solve drug quality problems. **Conclusion:** This blended teaching mode may be an effective alternative to conventional approaches in pharmaceutical education.

Keywords: Curriculum, Blended teaching mode, Pharmacokinetics, Pharmaceutical students.

Correspondence:
Dr. Pei Jing
Department of Pharmacy, The Affiliated Hospital of Southwest Medical University, Luzhou, Sichuan 646000, CHINA.
Email: jingpei.09@swmu.edu.cn

Prof. Zhirong Zhong
Department of Pharmaceutical Sciences, School of Pharmacy, Southwest Medical University, Luzhou, Sichuan 646000, CHINA.
Email: zhongzhirong@126.com

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INTRODUCTION

Pharmacokinetics is one of the main courses of pharmacy majors in medical colleges and universities in China. It occupies a very important position in the education and teaching process of undergraduate and graduate students and is also one of the frontier scientific development directions in the pharmacy field. This course applies kinetic principles and model processing methods to quantitatively describe the dynamic changes in the absorption, distribution, metabolism, and excretion of drugs after entering the body through various routes (such as intravenous injection, intravenous drip, and oral administration, etcetera.). Finally, mathematical expressions are used to clarify the relationship between the concentration (quantity) of the drug in different parts of the body and the time.[1] The course is highly practical, with long experimental projects, strong professional comprehensiveness and logical reasoning, and complex calculations.[2]

This course requires students to have the ability to design dosing regimens, master the changing laws of the whole process of drugs from entering the body to excretion, and apply theoretical knowledge to solve practical problems.[3] The course in pharmacokinetics is different from any core course in pharmacy, providing basic theories and basic methods for new drug design, drug quality evaluation, and guidance of clinical rational drug use. Pharmacokinetics is a subject between pharmacy and mathematics. It involves knowledge of pharmacy, pharmacology, advanced mathematics.[4] The content is rich, complicated, and profound, which involves a large number of mathematical formulas and many complex calculations as shown in supplementary Figure S1. But most domestic colleges and universities offer this course in the spring semester of the junior year, and the pre-course "Advanced Mathematics" is mostly offered in the autumn semester of the freshman year, which lead to the fact that most students do not have a solid grasp of relevant advanced mathematics knowledge or have

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forgotten it. Meanwhile, many students have not yet trained in corporate internship and clinical pharmacy practice experience, and they are relatively unfamiliar with new drug R and D, or the production and clinical medication guidance. As a result, it is difficult for both teachers to teach and students to learn.

In addition, the curriculum design of different majors is unreasonable, leading to a variety of problems in the teaching process, teaching quality is low. For example, some school's pharmacy and clinical pharmacy majors offer pharmacokinetics courses. However, due to the different professional orientations and training directions, the subject status and requirements of pharmacokinetics in various majors are different, and the corresponding syllabus is also different. The names of courses, experimental projects, time, and credits offered are different. Although these differences reflect the different emphases of professional training, they are not conducive to the execution of teaching tasks, the implementation, and management of the teaching process as well as the monitoring of teaching quality. Moreover, the original training programs and syllabus concepts are relatively old and conservative, failing to reflect the direction and achievements of the development of pharmacy and related majors in recent years, nor the comprehensiveness of the discipline, the autonomy, and innovation of students.

However, this course still widely adopts traditional classroom teaching, in which teachers teach the whole process and students accept passively. Students generally report that there are many knowledge points that it is difficult to understand, and the classroom content is boring and lacks interest in active learning. It is difficult to apply what they have learned, which leads to a bad teaching effect. So, this kind of traditional classroom teaching can no longer meet the needs of today's teaching. To improve students' interest in learning and cultivate innovatively and applied pharmacy talents, the reform of classroom teaching is urgent. Therefore, optimizing the teaching method and improving the teaching effect has become the key and difficult point to be solved in the teaching of this course. To carry out the teaching reform, some schools have adopted the mixed teaching mode that combined the small-scale and restricted online courses, divided classroom method, problem-based and case-based teaching methods, which have achieved some positive results. But the effect of the reform is still unsatisfactory. To improve students' classroom participation and teaching level, after comparing many methods, we plan to adopt the mixed teaching mode with online and offline to increase the interest in the classroom and the practicability of the course and improve the students' classroom participation.[5]

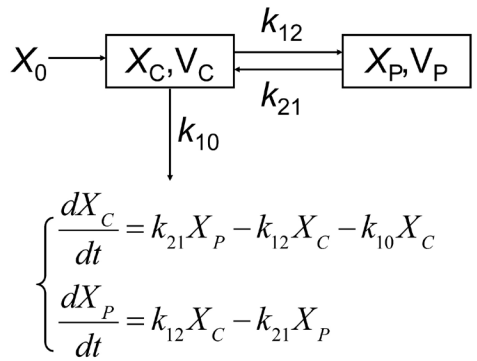

Figure S1: Examples of some formulas in the curriculum of pharmacokinetics. X_0: Initial dose; X_c: Central compartment dose; V_c: The apparent volume of distribution in the central compartment; X_p: Peripheral compartment dose; V_p: The apparent volume of distribution in the peripheral compartment; K_{12}: transport rate constant from the central compartment to peripheral compartment; K_{21}: transport rate constant from the peripheral compartment to central compartment; K_{10}: The first order elimination rate constant in the central compartment.

MATERIALS AND METHODS

The study is in terms of teaching reform and the blended teaching mode of online plus offline originated from Blended Learning (BL), which is an organic integration of online learning and face-to-face classroom teaching.[6] This teaching method not only makes full use of the advantages of online teaching but also makes up for the shortcomings of offline classroom teaching.[7] It can help us allocate classroom teaching resources and time more effectively, improve teaching efficiency, and improve students' learning effects.[8,9] The course has changed from the traditional single offline teaching and applied the "online + offline" mixed teaching mode.[10,11] As shown in Figure 1, the teaching reform of this course is mainly carried out in six steps.

Revise the Training Program and Syllabus

The success of all teaching reforms should start from the source and the ideology. To this end, we have revised the training program and syllabus, adjusted the teaching semester according to the teaching process of each major, the arrangement of the graduation practice period and the academic system, and unified the subject nature and subject status of the course. The next step will be to further revise the syllabus to unify the theoretical and practical hours, credits, experimental items, and assessment methods. This adjustment and unification are not only conducive to the cohesion of professional courses of different academic systems, but also the implementation and management of the actual teaching process.

Reconstructing the Teaching Staff

The present study plans to restructure the teaching staff. The teaching team will introduce teachers with backgrounds in advanced mathematics and network computing, members with practical experience in corporate new drug research and development, and doctors with practical experience in clinical pharmacy. These teachers with multi-backgrounds will form a multi-disciplinary teaching team, breaking the previous limitations of a single subject background and realizing a new "online + offline" hybrid teaching under the multi-disciplinary background cooperation.

Construction of Online Courses

At present, the pharmacokinetics course has not yet been launched online. In the context of the COVID-19 virus epidemic, it is not conducive to improving the teaching level and teaching effect. The primary task of the teaching team is the construction of online courses for this course.[12]

Prepare Micro-lecture Video

Micro-lecture technology breaks the limitation of teaching time and space, transforms the theorems and definitions of text description into wonderful videos for students, realizing the interactive transmission of intuitive media information, combining dynamic and static, sound and shape, which is conducive to students' in-depth thinking based on rich perceptual knowledge. For example, the *in vivo* pharmacokinetic experiments involve animal administration and animal blood sampling. This requires the higher practical ability of students. If the teacher records the experiment video first, the matters needing attention during the experiment and the details of the experiment can be perfectly presented. The learning effect will be improved compared with the oral explanation.[13]

Setting Up Chapter Quizzes

This stage is an online quiz stage, including chapter quizzes, teaching reflections, and excellent work presentations. Based on the completed online and offline classroom teaching stages, we will summarize the completion of teaching tasks and existing problems, carry out teaching reflection, optimize teaching plans, and supplement teaching content. Also, we will use the online platform to conduct chapter evaluations, design and arrange comprehensive test tasks, and select excellent works to display on it. It is aimed to let students click to view the multi-assessment scores to know their mastery of this chapter.

Set Up a Course Question Bank

The self-built pharmacokinetics-related exercises are aggregated into the online question bank of the course so that students can detect their deficiencies anytime and anywhere, and check and fill in the gaps at any time. And the wrong question bank is designed in the course question bank so that students can repeatedly strengthen their weak points.

Design Class Teaching Based on the Mixed Teaching Mode

The basic process of the hybrid teaching mode is divided into the following steps: (1) Teachers release teaching materials on the online platform and assign homework; (2) Students ask questions on time through autonomous learning; (3) Teachers and students communicate with each other to solve questions. According to the characteristics of the course, the setting of class hours, and the situation of students, we have designed a teaching plan that

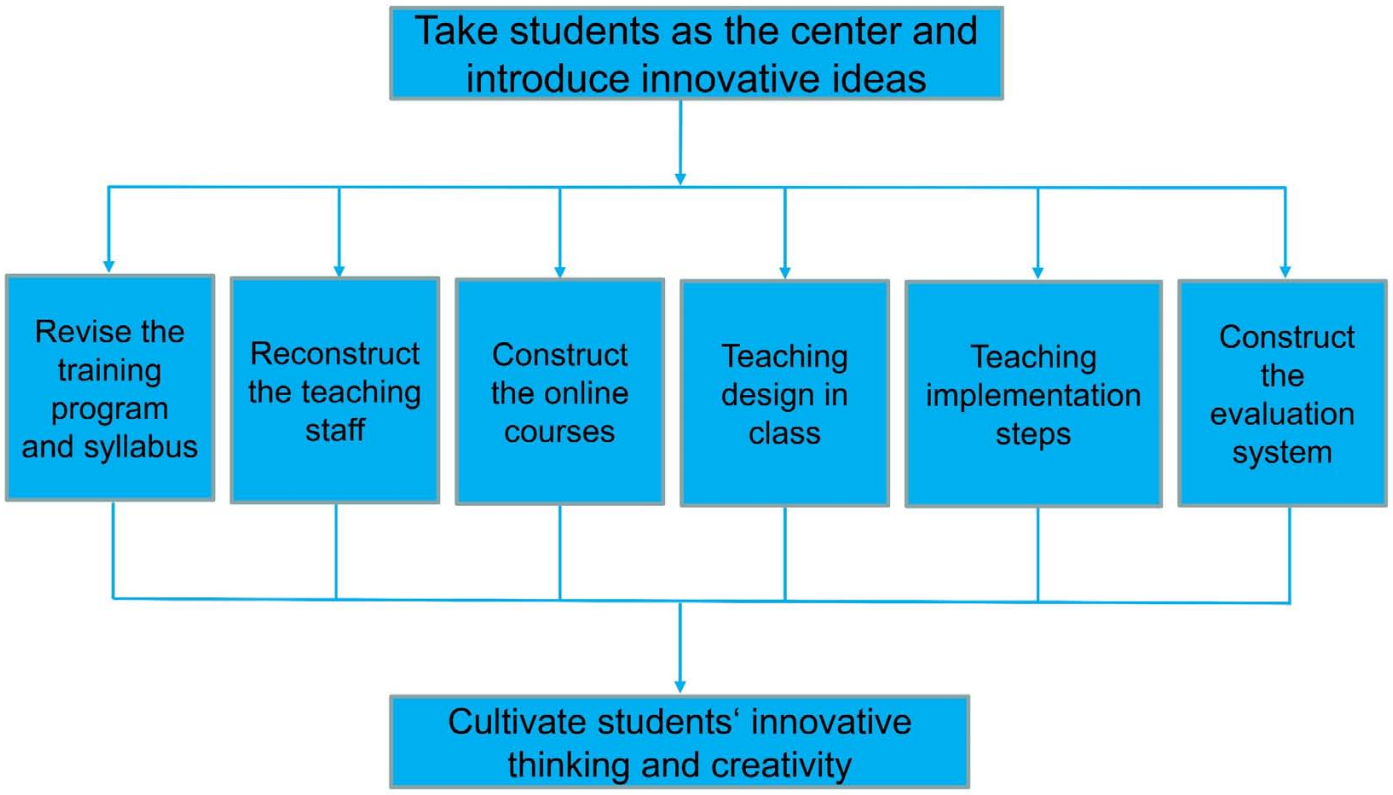

Figure 1: The implementation plan of curriculum reform based on the blended teaching mode of online plus offline.

is suitable for our students in a mixed teaching mode online with offline.

Online Teaching Design

The design of this module focuses on guiding learning before class and promoting learning after class, to exercise students' autonomous learning ability. Firstly, teachers prepare the teaching design according to the syllabus and make PPT courseware, and record teaching videos focusing on 1-3 basic theoretical knowledge of 10-15 min in length. Secondly, they upload teaching objectives, courseware, and videos to the online education platform. Thirdly, students use their mobile phones, or computer to learn while teachers monitor the time and frequency of online learning in the background. This part will account for a certain proportion of the performance assessment. Finally, a discussion area is set up after class, and students' questions are an important basis for teachers to prepare the offline lessons. The cases related to the course are arranged as the homework of the online teaching. After the students study online, they will use the knowledge they have learned and consult the relevant materials through group cooperation to prepare the analyzed cases for displaying in the offline classroom.[14,15]

Offline Teaching Design

After online learning, students have a preliminary grasp of basic knowledge and analysis ability for a simple problem. Teachers can timely get to know and answer students' difficult problems by asking questions in class. Face-to-face classroom communication can deepen students' understanding of key and difficult points, in which students come to the stage to analyze and explain the case, while the teachers ask and comment on the students' explanation.

This module focuses on case analysis, which is also a highlight of the reform measures for the teaching of pharmacokinetics. The case teaching method used in this course is an interactive and open model, which can keep pace with the times and has the characteristics of wide application and strong pertinence. Whether this method can achieve the expected teaching effect depends on the selection of cases. Teachers should prepare lessons carefully before class and select appropriate and diverse cases. It is more appropriate to explain 3 to 5 cases in class. The selected cases should be moderate in difficulty, in which too complex cases are difficult for students to solve in the initial study, while cases are too simple to improve students' ability to think and solve problems. Cases can be adapted from real cases based on the content of the teaching materials, and students can view problems from the perspective of clinical pharmacists to achieve clear teaching purposes. Taking the one-compartment model with intravenous administration as an example, the teaching design map is shown in Figure 2.

Teaching Implementation Steps Based on the Mixed Online and Offline Teaching Mode

The blended teaching evaluation system centered on the learning effect can comprehensively examine the students' learning situation in three periods of pre-class, in-class, and after-class, to achieve the goal of students' independent preview, review, and knowledge expansion. The teaching implementation steps of this course are shown in Figure 3, which are mainly divided into three parts: pre-class guide learning, in-class research learning, and after-class promotion learning.

Before class, teachers upload teaching resources in advance, including mind maps, guide PPT, concise videos of about 10 min, and practice questions. Students can preview through the guide PPT before class and master the main content. Teachers can check students' study time and answer questions on the teaching platform, which is conducive to discussing the common problems of students in offline teaching. This method makes up for the shortage of traditional teaching time and also cultivates the habit of students using the fragmented time to study independently.

During the in-class research learning, students are guided to actively participate in class discussions, which let students become the protagonists of the class. Taking the one-compartment model with intravenous administration as an example, this chapter requires students to master the calculation of the pharmacokinetic parameters. In class discussions, students can be divided into two groups, namely, "the change of drug concentration with time in blood" and "the change of drug concentration with time in urine". Each group prepares a 15-20-min PPT report. The members of the group and other groups of students can score the reporter and the group according to the PPT presentation and explanation. This inquiry-based discussion method can urge students to preview and think about the content before class and improve the learning effect through active learning and exploration.

For the after-class learning, the online test time is announced 1 hr in advance by the teacher. The test questions are randomly selected from the established question bank. Each student has different test questions to avoid plagiarism. Students answer the questions within the specified time, and the system automatically saves and submits them; students check and fill in vacancies according to their answers. Because the pre-class reading content needs to be completed by students independently, some students may fast-forward while watching short videos and reading PPT and complete the task by opportunistic means. The online test after class can eliminate this drawback. In this way, students can further strengthen their learning.

Construction of Evaluation System

The "online + offline" hybrid teaching evaluation system of the pharmacokinetics course is based on the principle of both process

assessment and result assessment, and fully considers the online and offline learning activities.[16] The teaching evaluation includes one first-level indicator, three second-level indicators, and five third-level indicators as shown in Table 1 and Figure 4.

To build a whole-process assessment of knowledge, skills, and quality, we formulate the assessment content, weight ratios, and assessment methods, including three modules of usual assessment, practical test, and final exam, to determine the final course grade. As shown in Figure 4, the evaluation of students' quality covers the whole teaching process. The curriculum assessment is transformed into a quantitative evaluation of indicators such as pre-class preview, classroom performance, and after-class discussion. The ideological education and curriculum teaching are integrated. Among them, the examination of the ideological education results of the course is added to the usual assessment. For example, in the discussion section of an online platform, a discussion thread of "My Views on Medication Safety" is set up for the application of pharmacokinetics in clinical medicine, and the scoring is based on each student's response.

Evaluation about the Hybrid Teaching Mode

At the end of the semester, a questionnaire survey was conducted to evaluate the implementation effect about the "online + offline" hybrid teaching mode. A total of 120 questionnaires were collected through an application program called as "questionnaire star". Statistical analysis was performed using students *t*-est. Differences among groups were assessed using one- or two-way analysis of variance.

RESULTS

As shown in Figure 5, this course implements the reform of the "online + offline" hybrid teaching mode, which enables teachers and students to form a dual-subject relationship. Based on the feedback of students' self-learning, we focus on the key points to give intensive and detailed lectures, and no longer cultivate cramming students. Therefore, students can flexibly arrange their learning progress and learning time according to their learning characteristics and learning methods. Moreover, there is a corresponding assessment for each independent study, and the

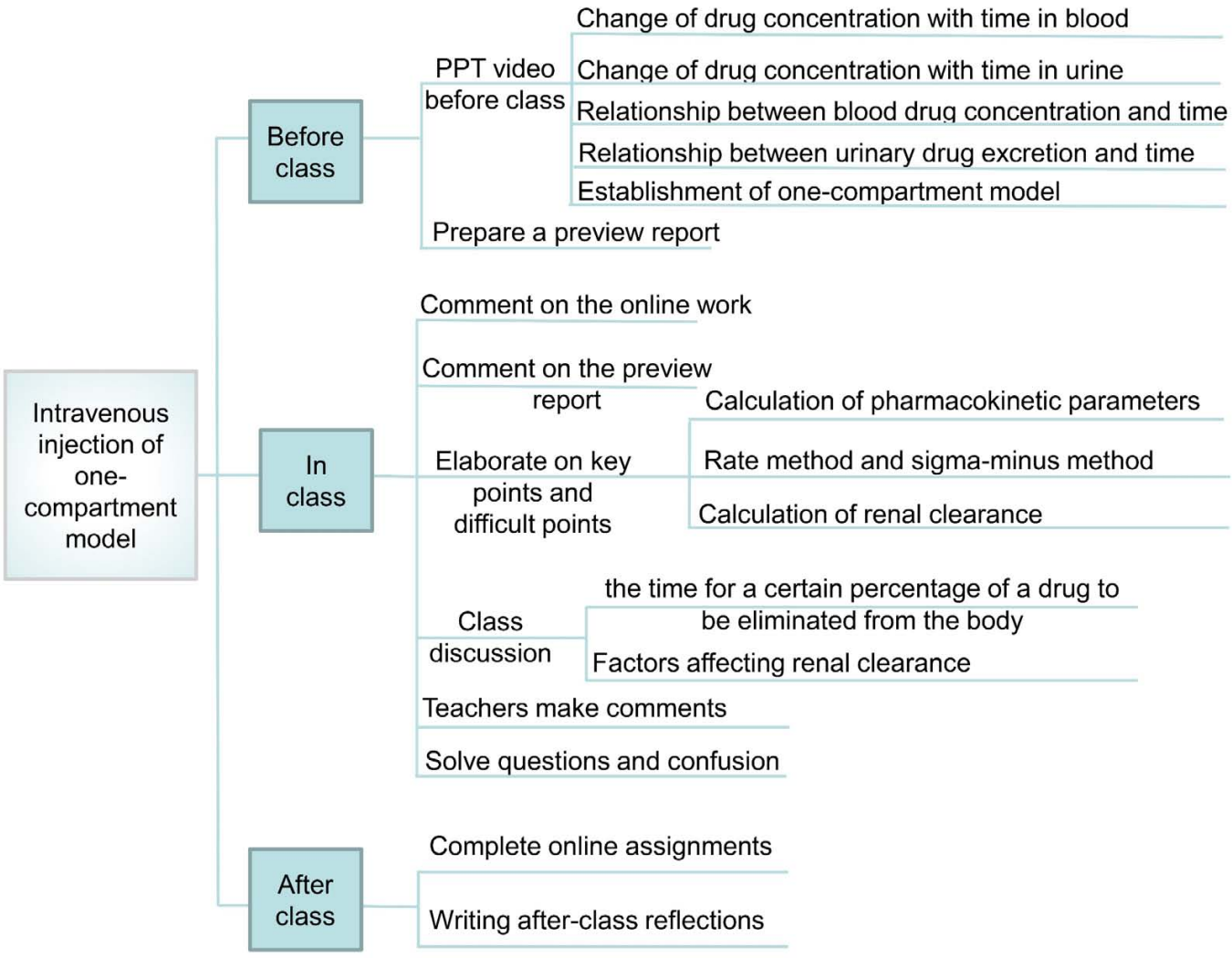

Figure 2: The design map of the blended teaching mode, taking the single-chamber model for intravenous administration as an example.

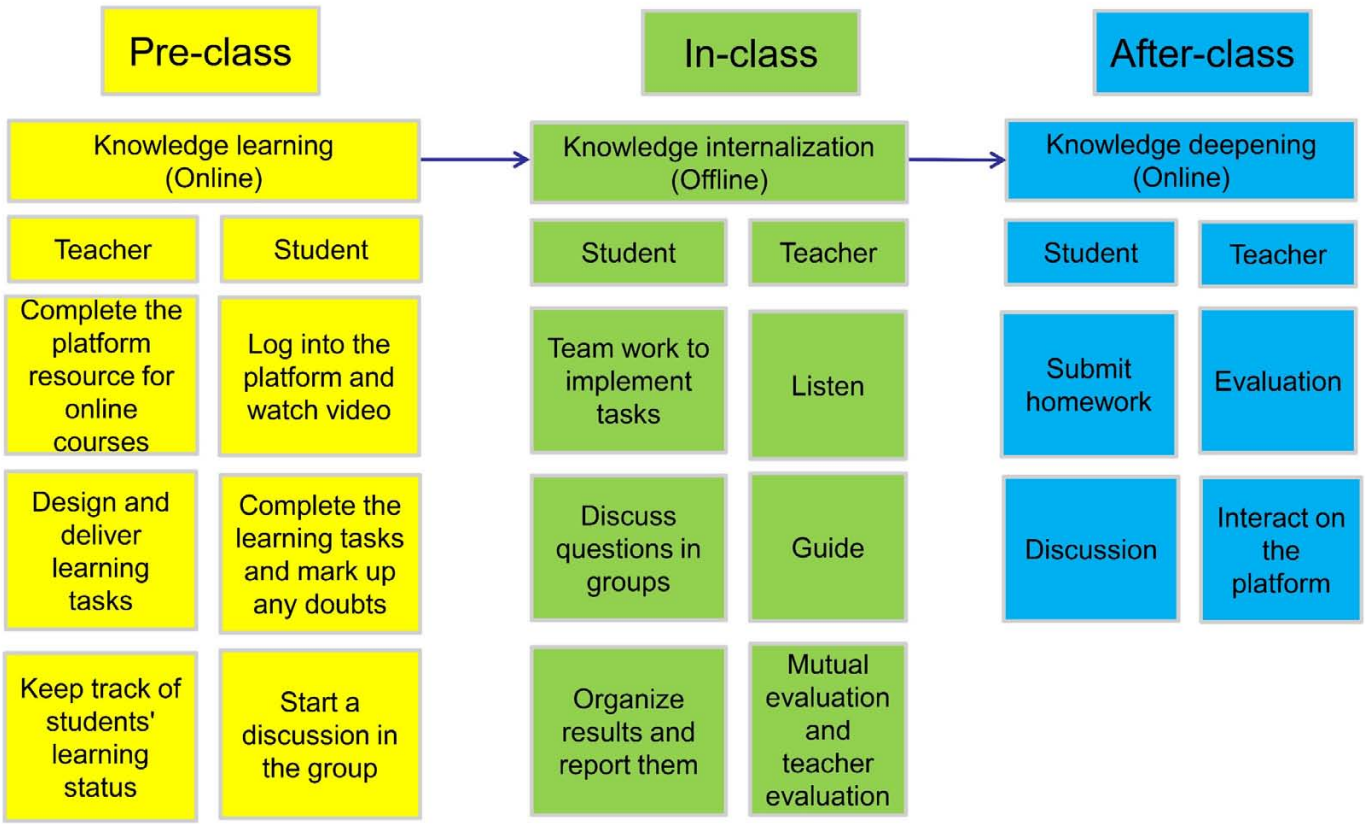

Figure 3: Implementation steps based on the blended teaching mode of online plus offline.

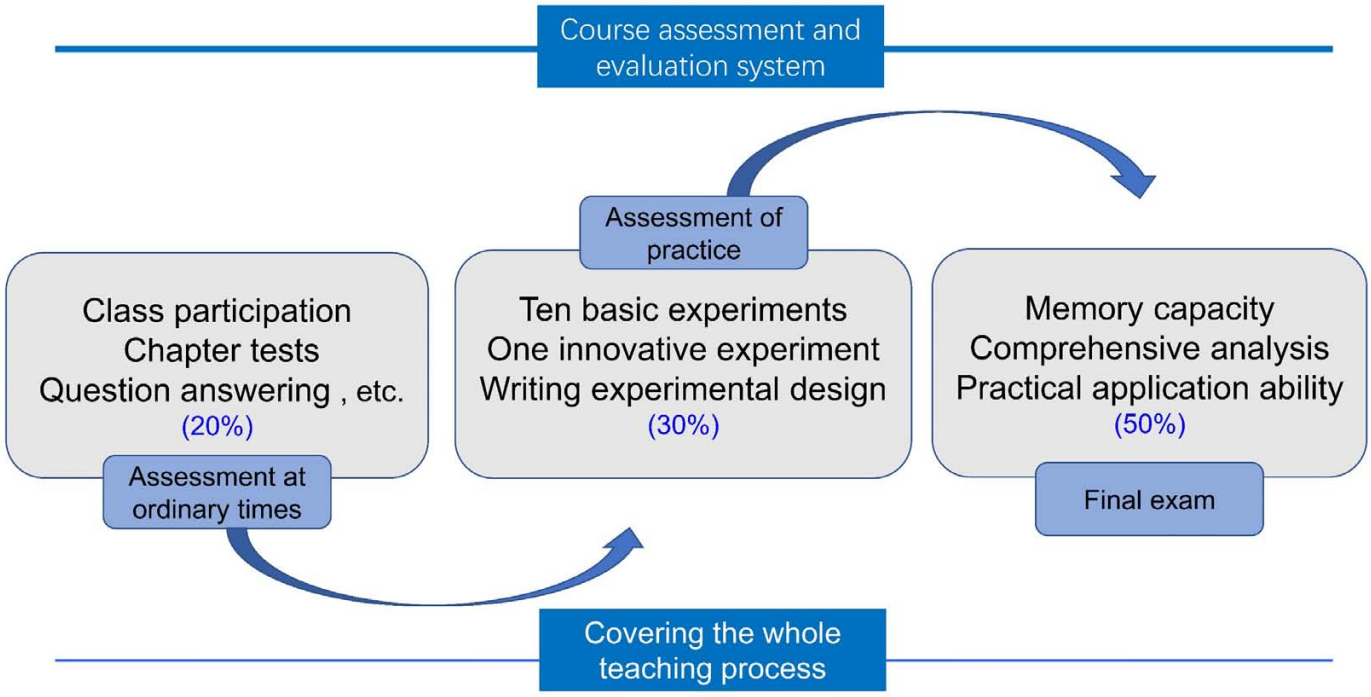

Figure 4: Pharmacokinetics course assessment and evaluation.

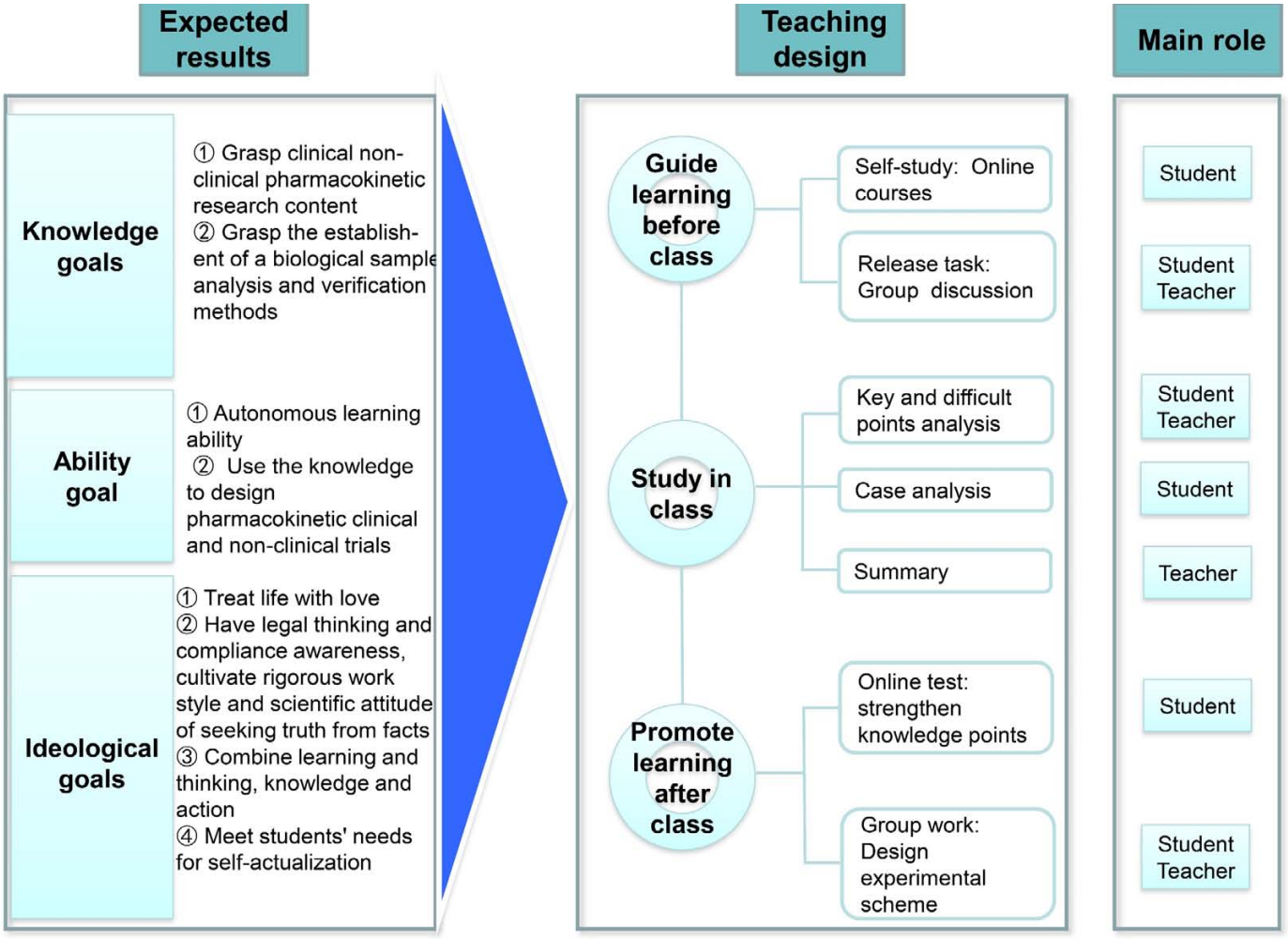

Figure 5: Results of curriculum reform on pharmacokinetics based on the blended teaching mode of online plus offline.

Table 1: Teaching quality evaluation system for the curriculum of pharmacokinetics based on the blended teaching mode of online plus offline.

First-level Indicator	Second-level Indicator	Third-level Indicator	Key Points of Evaluation	Subject of Evaluation
Total grade	Process assessment results.	Online study before class.	Learning micro-videos, group discussions, etc.	Teacher
		Offline study in class.	Theoretical study, experimental operation, etc.	Teacher Student
		Online study after class.	Submitted assignments and discussion.	Teacher
	Final assessment results.	Final exam.	Paper grades and experimental grades.	Teacher
	Attendance situation.		Late arrival, early leave, sick leave, personal leave, etc.	Teacher

learning effect is timely feedback, which improves the learning enthusiasm and sense of achievement. Through the statistical analysis of these questionnaires, it was found that among these questionnaires, 85% are glad to join the "online + offline" hybrid teaching mode, and 10% are willing to continue to try the "online + offline" hybrid teaching mode in other courses. These students generally believe that the "online + offline" hybrid teaching mode is rich and informative, which can stimulate their interest in learning. They believe that the class content arrangement is reasonable, the details are appropriate, the key points are prominent they said that they could better grasp the knowledge point. Among the questionnaires, 5% of the students keep neutral attitude to the "online + offline" hybrid teaching mode, they think there may be better ways to try.

DISCUSSION

Results showed that the mixed online and offline teaching mode can help to solve the problem of difficulty in both teaching and learning the pharmacodynamics course. It changed the students' rigid learning methods which are not conducive to the cultivation of applied high-quality pharmaceutical talents. Moreover, this teaching reform enhanced the students' knowledge and problem-solving ability. It achieved the course goals of cultivating students to be competent in medication guidance, drug quality control, and supervision positions, and to have the basic ideas and abilities to innovatively research and solve drug quality problems.

Firstly, it realized the knowledge goal. The case teaching method combined with others helps students firmly grasp the basic theory of pharmacokinetics, clinical and non-clinical pharmacokinetics research content; and master the establishment of biological sample analysis and verification methods, which lay the foundation for guiding clinical rational drug use and new drug research and development.

Secondly, it is the ability goal. The reform of curriculum teaching improved the students' autonomous learning ability and the ability to apply pharmacokinetic knowledge to analyze and solve clinical drug problems. Students could also use the knowledge to design and conduct pharmacokinetic clinical and non-clinical pharmacokinetic trials. They can master the pharmacokinetic profile of drugs from entering the body to the excretion, apply theoretical knowledge to solve practical problems, and can design drug delivery plans.

Thirdly, it is the ideological goals. It successfully infiltrates the elements of ideological education into the teaching, practice, and assessment of the course in a way of moisturizing things silently.[17] It also successfully enables students to understand the love and dedication behind the knowledge while learning professional knowledge, prompting students to treat life with love, have legal thinking and compliance awareness, and cultivate a rigorous work style and a scientific attitude of seeking truth from facts. It helps students to combine learning and thinking and cultivate the ability to analyze and solve problems, meeting the needs of students' self-realization.

In addition to the proposed blended teaching mode of online plus offline in this study, there are many other new teaching methods, such as Team-Based Learning (TBL), Problem-Based Learning (PBL), Case-Based Learning (CBL) and Research-BASED LEARNING (RBL). Therefore, in the subsequent teaching practice, these teaching methods can be innovated or combined for the better improving of the teaching quality.[18-20]

CONCLUSION

This study supports the feasibility of the online and offline mixed teaching mode in curriculum of pharmacokinetics, able to produce improvements in pharmaceutical students' learning outcomes. The blended teaching mode of online plus offline may be an effective alternative to conventional approaches in pharmaceutical education.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

BL: Blended Learning.

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