Ind. J. Pharm. Edu. Res., 2025; 59(1):416-424.
https://www.ijper.org

Original Article

Experimental Research on a Hybrid Teaching Model to Improve the Self-Directed Learning Ability of Pharmacy Students

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ABSTRACT

Aim: This paper explores applying and evaluating the hybrid teaching model based on an online course platform in biochemical experiment teaching at Jiaxing University. **Materials and Methods:** Students in grade 2019 majoring in Pharmacy at Jiaxing University were treated as the control group and the grade 2020 as an experimental group. The hybrid teaching model was used in the experimental group of grade 2020, whereas the traditional teaching model was used in the control group of grade 2019. At each end of the experimental course, class quizzes were administered to evaluate the learning performance of the two student groups. **Results:** A monthly exam of the theoretical course was conducted every four weeks and academic performances were assessed in two groups at the end of the semester. The two groups carried out the Self-Directed Learning (SDL) ability assessment at the beginning and end of the semester. The class quizzes of the laboratory course in the experimental group were significantly higher than those in the control group ($p<0.05$). Furthermore, the results of the last three month-quiz and final academic performance of students in the experimental group were higher than that of the control group ($p<0.05$) and the SDL ability assessment showed that four self-directed learning factors of the experimental group were significantly improved compared with those of control group. **Conclusion:** The performance of the biochemical experiment and theoretical course and the SDL activity of the students were enhanced based on a hybrid teaching model and using an online course platform.

Keywords: Biochemistry, Pharmacy, Self-directed learning, Teaching method.

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Received: 13-09-2023;
Revised: 19-01-2024;
Accepted: 22-10-2024.

INTRODUCTION

Biochemistry laboratory course is introduced to cultivate students' fundamental skills. Students can further deepen their understanding of the theoretical courses they have learned by studying experimental courses. They can enhance their hands-on ability through experimental practice, cultivate their Self-Directed Learning (SDL) ability and increase their ability to analyze and solve problems.[1,2] University students are in the critical phase of self-directed learning ability cultivation and effective guidance through experimental teaching practice of biochemistry at this stage can establish a solid foundation for their future career development.[3-6]

Experimental courses in biochemistry have traditionally been taught using a traditional didactic approach. By this traditional method, the teacher delivers knowledge and students passively receive knowledge and follow experimental instructions for experimental operations, which cannot adequately explain the experimental phenomena and solve problems that arise during the experiment course.[7,8] Due to the boring and profound principles of biochemistry experiments, students often complete the operations based on experimental instructions in the experiment class; they do not even understand the principles deeply and cannot give a full discussion on the experimental operation phenomena and experimental operation results.[9,10] This teaching method could not stimulate students' interest in biochemical experimental courses and might remove Self-Directed Learning (SDL) ability. To some extent, these types of experimental teaching methods can not cultivate the ability of students to analyze and solve problems.

In response to the above problems in the past few years, educators have reformed biochemistry experimental teaching. Dong

DOI: 10.5530/ijper.20255226

Fabao combined innovation and entrepreneurship concepts in biochemistry experiment teaching to improve engineering and innovation entrepreneurship skills.[11] Yi-Ying Wu *et al.* conducted a micro-video-specific experimental teaching design to expand the means of teaching biochemistry experiments and achieved a good teaching effect.[12] Furthermore, Shubing QIU showed integrating scientific research and innovation results into undergraduate experimental teaching.[13] Filiz Avc solved the problem of teaching virtual experimental teaching during the pandemic using a virtual experiment to conduct hands-on simulated experimental teaching activities at home.[14] Even though few studies have utilized contemporary instructional models to enhance the SDL ability of students.

The SDL concept has attracted widespread interest in education research over the past few years. SDL ability plays a crucial role in solving problem processing. The existing research on SDL has demonstrated correlations with academic performance, especially in online environments.[15-17] Recent research also suggests blended learning environments culture their self-directed learning abilities.[18,19] However, there are few studies about approaches to teaching by hybrid teaching methods in experimental course design.

This study analyzed the effects of blended teaching and instructional design approaches on students' SDL in biochemistry experiment courses. The hybrid teaching model is an important teaching method to improve students' self-direct learning ability; however, it is not very common to use and carry out systematic teaching attempts in biochemistry experiment teaching.[20-23] The possible reason is that the hybrid teaching model should be equipped with completed teaching resources and adequate learning resources with the help of intelligent teaching tools. These teaching resources need to be built systematically, which requires a lot of time and cost and there are few attempts to use a hybrid teaching model for experimental instruction.

In this article, we introduced the application and evaluation of the blended teaching method in Biochemistry experimental teaching in our college. The study population was all year-two Pharmacy students of Jiaxing University. Students of Grade 2020 were treated as the Experimental Group (EG) and Grade 2019 as the Control Group (CG). The hybrid teaching model was used in the experimental group, whereas the traditional teaching model was used in the control group. Furthermore, we used micro-videos to help students understand the experimental principles, results and phenomena. To study the quantitative indexes of the hybrid teaching model on students' experimental assessment, academic performance and SDL ability assessment were conducted to evaluate the teaching effect of a hybrid teaching model application in an experimental biochemistry laboratory course.

MATERIAL AND METHODS

Teaching method

Teaching experiment grouping

A total of 128 students enrolled in the Biochemical experimental course, with a range of 63 students in grade 2019 as a control group and 65 students in grade 2020 as the experimental group. The experimental group adopted the hybrid teaching method and the control group adopted the traditional one. The teaching methods of the CG and EG were shown in Figure 1. The teaching contents, number of teaching hours and instructors were the same.

The teaching method of the control group

Before the biochemical experiment course, we released the preview experimental content by class notice. During the class, teachers taught the principles and operation of the experiment and the students followed the experimental manual. The class quizzes were conducted at every experimental course. After the class, they finished the experiment report.

Teaching resources for experimental groups

We constructed a biochemistry experiment online course using the Wisdom Tree course website with micro-lessons, test questions, discussion questions and other digital resources to carry out experimental teaching for hybrid learning. We used the Wisdom Tree platform to carry out blended teaching of biochemistry experiment courses in grade 2020. The name of the online course is Biochemistry and the course website is (Biochemistry Experiment-Wisdom Tree (zhihuishu.com) https://coursehome.zhihuishu.com/courseHome/1000003521#teachTeam). The website contained 18 teaching videos, a total of 204 min. Teaching resources include 18 teaching videos for a total of 204 min (Table 1), 98 test questions (5-6 for each experiment), 82 cases and discussions (4-5 for each experiment); and 55 experimental extension materials, (3-4 for each experiment).

The biochemistry experiment course was designed based on mastery of the basic theory, discuss the experimental phenomena in conjunction with the experiments and expand their learning of the experiments to some extent.

Class-quiz

The class quiz was tested after biochemical experiments, including experimental principles of 3 questions, experimental operations of 3 questions, experimental phenomena and analysis of 3 questions. The question type and question score of the class quiz were shown in Table 2.

The teacher used the Wisdom Tree course platform to release the experimental test questions. The test questions were released at the end of the experimental class to assess students' learning

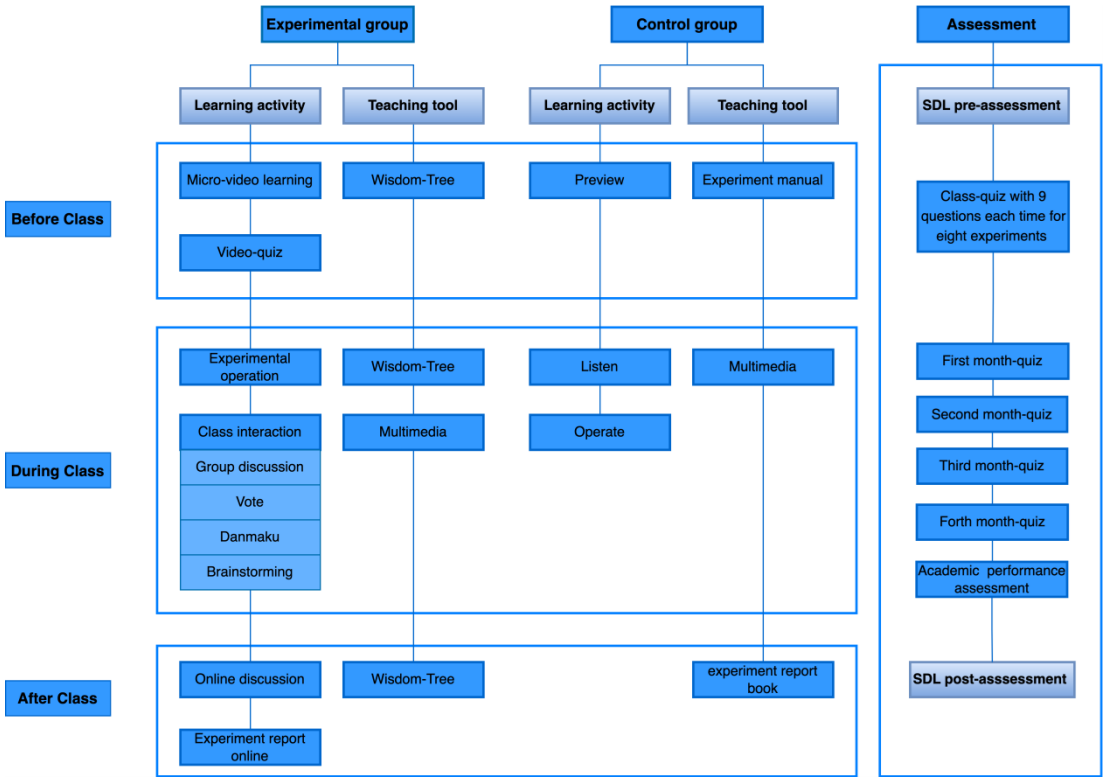

Figure 1: Flow chart showing the teaching method used in the CG and EG.

Table 1: **Micro-video list of biochemistry experiment course on the Wisdom Tree platform.**

Sl. No.	Chapter	Section	Duration
Chapter 1	Basic knowledge of biochemical experiments	1.1 Laboratory Rules	8 min
		1.2 Basic operations of biochemistry experiments	8 min
		1.3 Spectrophotometric techniques	9 min
		1.4 Washing of glass instruments	7 min
		1.5 The basic principle and operation of electrophoresis	12 min
Chapter 2	The basic theory of experiments	2.1 Properties of proteins	10 min
		2.2 Enzyme specificity	10 min
		2.3 Factors affecting the speed of enzymatic reactions	9 min
Chapter 3	Spectrophotometric techniques	3.1 Bicarbonyl urea method to determine protein concentration	14 min
		3.2 Determination of yeast sucrase mitochondrial constant	10 min
Chapter 4	Electrophoresis Technology	4.1 Electrophoresis Technology	11 min
		4.2 Separation of serum proteins using cellulose acetate film electrophoresis	10 min
Chapter 5	Chromatography	5.1 Extraction of lipids and thin layer chromatography of lipids	19 min
		5.2 Purification of serum proteins using gel chromatography	17 min
		5.3 Protein purification using affinity chromatography	10 min
Chapter 6	Comprehensive experiments	6.1 Extraction and content determination of vitamin C in food	15 min
		6.2 Extraction and identification of astaxanthin from shrimp shells	12 min
		6.3 Polymerase chain reaction	13 min

outcomes in two groups. The relevant class quiz questions for one of the comprehensive experiments on enzyme properties are listed in Table 3.

Assessment of the SDL ability

The SDL ability was assessed using the assessment scale developed by Wang Xiaodan *et al.* Cronbach's alpha coefficient for the original scale was 0.929, with a reliability of 0.992.[24] This scale consists of 30 items distributed across two subscales (self-motivated beliefs and objective behavior) and six factors (self-motivation, learning beliefs, setting learning goals and plans, self-monitoring and regulation, information processing and communication and cooperation). Furthermore, the Likert scale is a 5-point response scale, with a score of 5-1 representing "fully meets," "generally meets," "fair," "not fully meets," and "not at all meets." The scale of the six factors is based on a 5-point response system, with a 5-1 scale representing decreasing degrees of "fully conform," "basically conform," "generally conform," "not conform," and "not conform at all," with a score ranging from 30-150. The SDL ability was assessed between EG and CG before and after the semester.

Monthly exam and academic performance assessment

Four monthly exames for the biochemistry theoretical course were conducted every four weeks, each consisting of 40 single choice questions and 10 multi-choice questions. The first month-exam covered 1-4 weeks of teaching content, the second month-exam covered 5-8 weeks of teaching content, the third month-exam covered 9-12 weeks of teaching content and the fourth month-exam covered 13-16 weeks of teaching content. The exames were conducted on the Medical Education Question Bank of China People's Health Publishing House(https://tk.ipmph.com/exam/a/adminlogin;JSESSIONID=0db19885008942a3bd8ab73caff1d7e2). The teachers conducted the academic performance assessment of the experimental group and the control group according to the established lecture plan and syllabus and the papers were automatically composed by using the Medical Education Question Bank of China People's Health Publishing House(https://tk.ipmph.com/exam/a/adminlogin;JSESSIONID=0db19885008942a3bd8ab73caff1d7e2) and when setting the difficulty parameters of the papers, the sampling rule of the questions was set to "easy: medium: difficulty=1: 3: 1". There are 18 difficult questions, accounting for 21% of the paper; 52 medium difficult questions, accounting for 58%; 18 easy questions, accounting for 21%. The Experimental section and questions quantity of the laboratory course were show in Table 4.**Table 4:**

After the examination, the marking is completed by the teachers and other teachers involved in the teaching and research group. The marking work is performed by the standard answers and grading standards provided by the question bank system and the director of the teaching and research department completes the audit work.

Statistical analysis

We compared the factor scores of SDL ability by the CG and EG before and after the clustering results were generated using paired

Table 2: Questions type and questions score of the class quiz.

Experimental section	Questions objective			Total number
	Experimental principles	Experimental operations	experimental phenomena and analysis	
Properties of proteins	3	3	3	9
Enzyme specificity and factors affecting the speed of enzymatic reactions.	3	3	3	9
Determination of yeast sucrase mitochondrial constant.	3	3	3	9
Separation of serum proteins using cellulose acetate film electrophoresis.	3	3	3	9
Extraction of lipids and thin layer chromatography of lipids.	3	3	3	9
Purification of serum proteins using gel chromatography.	3	3	3	9
Protein purification using affinity chromatography.	3	3	3	9
Extraction and content determination of vitamin C in food.	3	3	3	9
Total	24	24	24	72

Table 3: Class-quiz of experiment enzyme properties.

Sl. No	Questions	Answers	Questions Objective
1	Which of the following factors can affect the speed of enzymatic reactions?	A. Substrate concentration B. Temperature C. PH D. All of the above are correct.	Basic theory
2	What are the types of enzyme specificity?	A. Absolute Specificity B. Relative Specificity C. Stereoisomeric specificity D. All of the above are correct.	Basic theory
3	Starch hydrolysis process	A. Starch-dextrin-maltose-glucose. B. Starch-glucose-maltose. C. Starch-maltose-glucose. D. Sstarch-dextrin-glucose-maltose.	Basic theory
4	In the experiment on the effect of PH on the speed of enzymatic reaction, one drop of 1 mol/L HCl was added to tube 4 before adding iodine solution to acidify it. Why?	A. Prevents side effects from occurring. B. Has no effect; this step is not needed and can be omitted C. Do not know. D. The operation is necessary and this operation can be performed at the beginning of the experiment.	Operational skill
5	The incorrect use of pipettes	A. Right-handed holding the tube. B. Left hand holding the tube. C. Thumb blocking the mouth of the tube. D. Forefinger blocking the mouth of the tube.	Operational skill
6	Temperature affects the speed of enzymatic reactions in the operation; then which operations need to be taken?	A. The reaction solution is taken from. the tube at 60° to act with iodine B. Three test tubes can be operated in sequence C. The 60 tube can react directly with the iodine solution. D. None of the above statements is correct.	Operational skill
7	What is the reason for the yellow color of the reaction solution if it interacts directly with iodine?	A. No saliva was added. B. The enzyme activity is strong and has hydrolyzed the starch. C. Do not know. D. No iodine solution was added.	Scientific analysis
8	What is the treatment method if the reaction solution turns yellow directly by interaction with iodine?	A. May be wrong, do it again. B. Dilute the saliva and do it again. C. Wait a while and it will turn purple. D. Do not know.	Scientific analysis
9	Color change of starch hydrolysis products in reaction with iodine solution	A. Blue-fuchsia-yellow B. Yellow-blue-violet C. Blue-yellow-violet D. Yellow-fuchsia-blue	Scientific analysis

samples and independent T-test. The χ^2 -test was used to compare the age, gender composition, grade point average of last semester and entrance score between the two groups. All statistical analysis was performed using SPSS V.27 for Windows. Age and scores for each factor of the SDL ability assessment scale were expressed as mean standard deviation and *P* values less than 0.05 were regarded as statistically significant.

RESULTS

The CG consisted of 65 students from the 2019 academic year and the EG consisted of 63 students from the 2020. Our descriptive statistical analysis found no disparities (Table 5) in the sample's gender distribution, age, enrollment scores, or GPA of last semester. No differences exist between students' enrollment scores or between male and female ratios.

The class quizzes were tested on basic theory, operational skills and scientific analysis. Based on the test results of the experimental group and control group, the results of questions 1-9 found significant differences between the experimental group and the control group in terms of basic theory, operational skill and scientific analysis of experimental phenomena, indicating that blended teaching has improved students' understanding of experimental principles, their ability to operate experiments and analyzed experimental results. Figure 2 depicts the mean scores for class quizzes across eight experiments for two groups. There were significant differences between EG and CG across all nine queries and eight experiments.

The results of the four-month exames and the academic performance were presented in Figure 3. The results showed no significant difference in the scores of the first test between the experimental group and the control group. From the second month-exam, the month-exam score of the experimental group students are higher than the control group and the academic performance scores of the experimental group are also higher than the control group. The experimental teaching was arranged once per week from the 5th week to the 13th. Before the experimental teaching, no difference was observed in the scores for monthly quizzes of the experimental and control groups. One month after the beginning of the experimental teaching, the month-exam scores of the experimental group were higher than those of the control group and the academic performance scores of the experiment were also higher than those of the control group. The results showed that the hybrid teaching model positively impacts understanding the basic theory of the courses.

SDL ability assessment

At the end of the semester, significant differences ($p<0.05$) were observed between EG and CG in four SDL ability factors (setting learning goals and plans, self-monitoring and regulation, information processing and communication and cooperation). Figure 4 depicts the mean scores of two factors in SDL ability pre- and post-assessment in EG. Mean scores of self-motivation, learning belief, two factors pre-experiment and post-experiment were no significant differences between EG and CG.

Table 4: Experimental section and questions quantity of the laboratory course.

Questions type	Questions quantity	Score per question	Total score
single-choice questions	50	1	50
multiple-choice questions	5	1	5
matching questions	15	1	15
fill-in-the-blank questions	10	1	10
terminology questions	5	2	10
short-answer questions	3	334	10
Total	88	—	100

Table 5: Demographic characteristics of study participants.

	Category	Control (*n*=65)	Experiment (*n*=63)	χ2 /t	*p*-value
Entrance score		571.73±2.73	571.90±2.86	-2.368	0.19
Gender	Female	32(49.2%)	32(51.8%)	0.029	0.251
	Male	33(50.8%)	31(49.2%)		
Age	Year	19.32±0.42	19.24±0.45	0.225	0.894
GPA of last semester (5.0 point scale).	>3.5	16(24.6%)	20(31.7%)	0.053	0.974
	3.0-3.5	25(38.5%)	25(39.7%)		
	<3.0	24(36.9%)	18(28.6%)		

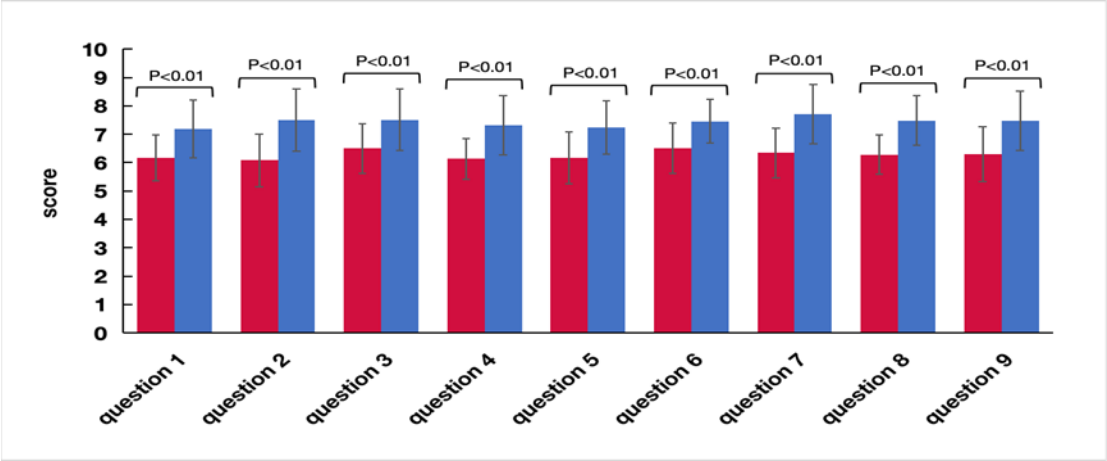

Figure 2: class-quiz results of CG and EG. Data are presented as means±standard deviation; * $p<0.05$.

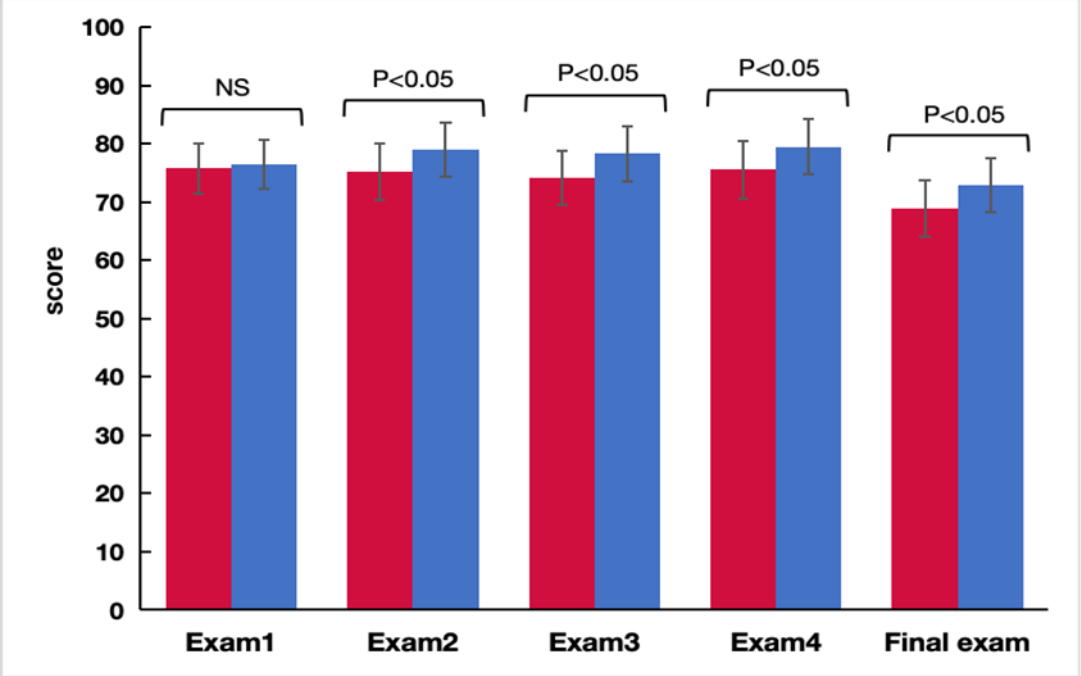

Figure 3: Month-quiz and academic performance results of CG and EG. Data are presented as the means±standard deviation; * $p<0.05$.

DISCUSSION

In previous studies, the blended teaching model has been proven to achieve good teaching effects in several medical college courses, such as college clinical dental education,[25] neurologic examination[26] and nursing research.[27] These studies indicate that the blended teaching model benefited students' learning, stimulated enthusiasm, cultivated clinical thinking ability and improved teaching quality.

In order for students to understand the basic principles of experimental courses, a hybrid method of instruction is indispensable. Researchers have carried out reforms in this area and achieved certain results. We have explored a hybrid teaching model for biochemistry experiments using digital teaching resources and smart teaching tools with the results of first-class curriculum construction. For the hybrid teaching model, before class, students, through the micro-video, can see a whole image of the experimental operation, which will make it easy to understand basic theory, operational skills and scientific analysis of experimental phenomena. For the traditional teaching method, students lack the image of experimental teaching and focus on the experimental operation process, so understanding the basic theory, operational skill and scientific analysis is ignored. Some students struggle to understand even the most basic principles of experimental theory. Compared with the traditional teaching method, the class quiz result indicated that the hybrid method improved the understanding of basic theory, operational skills and scientific analysis of biochemistry experiments.

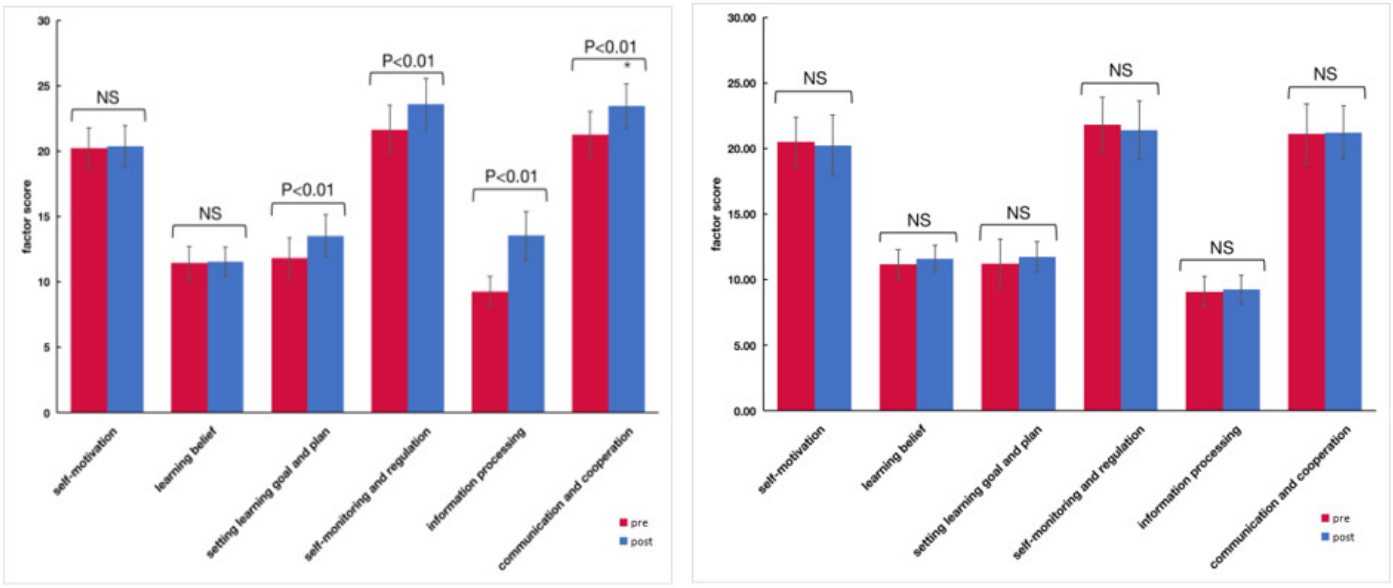

Figure 4: Assessment of SDL ability of EG and CG. Data are presented as the means±standard deviation; * $p<0.05$ ** $p<0.01$ and NS: no significant difference.

An analysis of the reason may be that the biochemistry experimental content and theoretical content are closely linked and students deepen their understanding of the basic theory of the experiment. Another possibility is that students who take a hybrid experimental course in theoretical learning can engage in in-depth thought, enhancing the learning effect of learning basic theory.

SDL assessment results showed that the hybrid teaching method could improve four factors of SDL ability (setting learning goals and plans, self-monitoring and regulation, information processing and communication and cooperation). Mean scores of self-motivation, learning belief, two factors pre-assessment and post-assessment were no significant differences between EG and CG. Setting learning goals and plans, self-monitoring and regulation, information processing and communication and cooperation belong to SDL activity. However, setting learning goals and plans, self-monitoring and regulation belong to SDL motivation and belief. Our research showed that improving SDL activity by a hybrid teaching method in an experiment course is feasible, but improving SDL motivation and belief in an experiment course is difficult. These findings indicated that using the hybrid teaching model to give pharmacy students in experiment courses improved the students' experimental and theoretical academic performance.

CONCLUSION

The hybrid teaching method is effective in improving students' self-learning activity. Using hybrid methods in biochemistry experimental teaching could improve students' class quizzes and academic performance.

ACKNOWLEDGEMENT

We are grateful to WisdomTree for their technical support and assistance during the course of the project. We are also very grateful to all the Pharmacy students of the Grade 2019 and 2020 for their participation.

FUNDING

This work was supported by province-level online and offline first-class courses of Zhejiang China (Grant no 2019-671), Virtual simulation experiment teaching projectof Zhejiang China (Grant no 2020-346), University-level Research project on practical teaching reform (2020-8518ZY2306), Off campus practical education base for general practice medicine (2023-417973201) and the 2023 SRT project of Jiaxing University, China.

AUTHORS CONTRIBUTIONS

Huang Xu and Dong Han contributed to the design of this study. Si ying Lu contributed to teaching data collection and analysis. Huang Xu and Dong Han contributed to the original manuscript writing and data analysis. Xiang peng Ren contributed to the manuscript revision. All the authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

SDL: Self-Directed learning; **EG:** Experimental Group; **CG:** Control Group.

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Cite this article: Xu H, Lu S, Zeren Q, Ren XP, Han D. Experimental Research on a Hybrid Teaching Model to Improve the Self-Directed Learning Ability of Pharmacy Students. Indian J of Pharmaceutical Education and Research. 2025;59(1):416-24.