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Developing a BOPPPS (Bridge-in, Objectives, Pre-assessment, Participatory Learning, Post-assessment and Summary) model combined with the OBE (Outcome Based Education) concept to improve the teaching outcomes of higher education

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The teaching objectives of traditional approaches in higher education emphasize mostly students' mastery of knowledge and have insufficient directionality to social needs. In this study, we developed a BOPPPS (Bridge-in, Objectives, Pre-assessment, Participatory Learning, Post-assessment and Summary) teaching model combined with the OBE (Outcome Based Education) concept to enhance the teaching outcomes. Firstly, based on the graduation requirements and professional training objectives of students, we divided the course objectives into three dimensions (knowledge, ability and quality), and further specified into index points. Then, the teaching content of each chapter was set to correspond with the index points. Finally, the BOPPPS teaching model was used to meet each requirement. Clinical biochemistry testing course was used as a model to assess the effects of the teaching reform. After the class, the teaching effect was analyzed based on the questionnaire surveys from the students and their scores of both the chapter and final examinations. The results showed that compared with the traditional approach, the BOPPPS teaching model combined with the OBE concept has demonstrated a notable enhancement in student engagement, and significant improvement of their mastery of knowledge, application skills, and problem-solving abilities. The examination scores of the BOPPPS group were markedly higher than those of the traditional group. Moreover, the difference between the two groups diverse assessment scores was much bigger than that between the two group examination scores. Our study indicates that the BOPPPS teaching model combined with the OBE concept is a highly effective teaching model for enhancing the learning effectiveness of students.

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Introduction

Traditional higher education's unidirectional knowledge transfer and unitary assessment methods inadequately address social needs, resulting in compromised teaching effectiveness. Therefore, how to redesign the curriculum training objectives, update the curriculum content system, and innovate teaching and assessment models to cultivate talents with good practical, innovative, and comprehensive abilities is an urgent problem to be studied and solved.

OBE, known as result-oriented education or goal-oriented education, originated from the Western higher education reform trend in the 1980s and has made remarkable contributions to education systems worldwide (Shaheen, 2019). Since OBE is oriented towards expected outcome goals, the teachers need to clarify what is most important to students before organizing, implementing, and evaluating teaching (Yen, 2016; Singh and Ramya, 2011). That is, teachers should clarify the abilities that students should possess upon graduation, and determine educational goals according to the required abilities in the profession to ensure that students can adapt to their job positions in a timely manner after graduation (Akçayır and Akçayır, 2018; Zhang, 2020). On this basis, appropriate teaching activities are designed to ensure the achievement of expected goals, the core of which is to emphasize that teaching should be reasonably designed and optimized around the expected learning outcomes, ensuring that students meet graduation requirements and acquire the comprehensive skills that should be possessed during employment (Dai et al., 2017; Rajaee et al., 2013). In summary, the OBE concept is based on the future effectiveness of students, emphasizing what students have learned rather than what teachers have taught, which can effectively improve the problem of students' insufficient comprehensive abilities in traditional learning and provide new ideas for current education and teaching (Sajdak and Kościelniak, 2014; Tan et al., 2018).

However, altering teaching concepts is not enough. Specific teaching models and methods need to be reformed. The BOPPPS model, which originated in Canada and was initially created based on the need for teacher qualification certification, emphasizes student-centered participatory teaching and meets the requirements of the times (Instructional Skills Workshop Network, 2023). Since the BOPPPS teaching model advocates a student-centered approach, teachers are required to utilize diversified teaching methods, optimize teaching design, and increase classroom interactivity. This model has provided teachers with a highly organized teaching framework to ensure high-quality and efficient teaching, which mainly includes Bridge-in, Objectives, Pre-assessment, Participatory-Learning, Post-assessment, and Summary. The initial letter of each part is combined into BOPPPS as the abbreviation of this teaching model. The meanings and characteristics of each part are as follows: B (Bridge-in): the introduction and guidance of the class, introducing the teaching content, attracting students' attention and stimulating their interest; O (Objectives): the teaching objectives and expected teaching outcomes, clarifying the teaching objectives and enabling students to understand what can be done by learning the knowledge; P (Pre-assessment): the pre-class testing process, which helps teachers understand students' mastery degree of relevant knowledge, laying the foundation for subsequent teaching; P (Participatory-Learning): the core module of the BOPPPS model and the main part of classroom teaching, allowing students to participate in classroom activities and guiding them to learn independently; P (Post-assessment): the assessment to understand students' learning effectiveness, whether teaching objectives have been achieved, what the students have learned, and provide feedback on the learning effectiveness; S (Summary): Summarizing this lesson and introducing the content of the next lesson, collecting feedback, praising, and guiding students to summarize and reflect on what they have learned. The BOPPPS model has been employed in the teaching of many subjects, such as physiology education (Liu et al., 2022), oral histopathology (Wang et al., 2021), dental materials education (Yang et al., 2019), healthcare and management education (Ma et al., 2021). And the model has been proven to be highly effective for improving the learning effectiveness of the students.

In this study, the OBE concept and BOPPPS teaching model were combined to improve teaching outcomes of higher education. First, the course outcome goals were divided into three dimensions – knowledge, ability and quality, which were further specified into index points. Then, the teaching content of each chapter was set to correspond to the index points. Finally, the BOPPPS teaching model was used to achieve each requirement. Clinical biochemistry testing course, the core course of medical laboratory technology subject, was used as a model to assess the effects of the teaching reform. This course covers a wide range of knowledge and complex content, and plays an important role in medical theory and practice. Seven classes of undergraduate juniors majoring in medical laboratory technology were randomly divided into two groups. The BOPPPS group containing three classes utilized the BOPPPS teaching model combined with the OBE concept. The traditional group containing the remaining four classes used the traditional teaching approach. After the class, the teaching effect was analyzed based on the questionnaire surveys from the students and their scores on both chapter and final examinations.

Approaches

Design of the BOPPPS teaching model combined with OBE concept. Based on the OBE concept and the implementation process of BOPPPS teaching model, this study constructed the idea of "student-oriented, result-oriented, and continuous improvement", and designed the BOPPPS teaching model combined with OBE concept (Fig. 1).

Implementation steps of the BOPPPS teaching model combined with OBE concept. The OBE education concept emphasizes the achievement orientation. We divided the outcome objectives into knowledge objectives, ability objectives and quality objectives, and further subdivided them into index points corresponding to graduation requirements based on the specific training goals and graduation requirements of students in different majors. The teaching content was optimized based on these index points, ensuring that the course teaching outcomes support graduation requirements. This study utilized the six-phase BOPPPS teaching model to attain the targeted index points (Fig. 2).

Bridge-in. The effective course bridge-in can guide students well to have strong interest and motivation, and help students focus on or connect to the course content, improving the completion of the index points from the source. In this stage, the teachers focused on explaining the importance of this course learning around the index points, telling stories and current events closely related to the core teaching content or the previous related teaching content, organically linking the students' existing foundation with the content they would learn, and put forward questions related to the teaching topic to guide students into the core content of the teaching link. For example, in the chapter of "the biochemistry test of hepatobiliary diseases" of clinical biochemistry testing course, bilirubin metabolism and the occurrence mechanism of jaundice are the key and difficult contents.

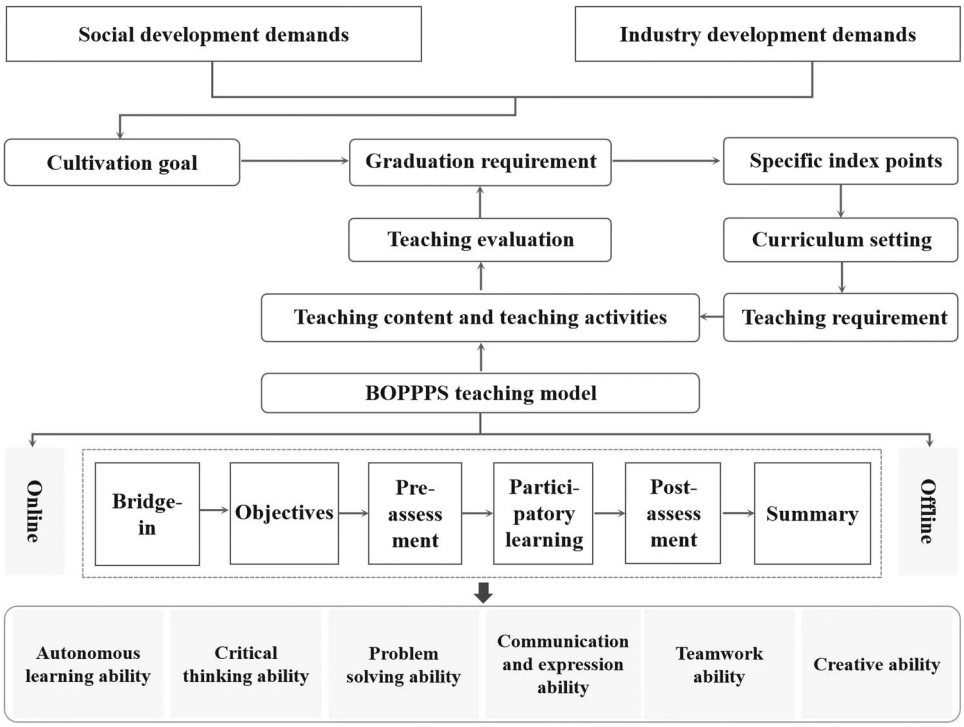

Fig. 1 Schematic diagram of the BOPPPS teaching model combined with OBE concept. Cultivation goals and corresponding graduation requirements were determined based on social and industry development demands. Then, index points were specified to meet the requirement. According to the points, the curriculum and its teaching requirements were set, and corresponding teaching activities were launched by BOPPOS teaching model. Finally, evaluations were conducted to feed back the teaching effect and provide reference for teaching improvement.

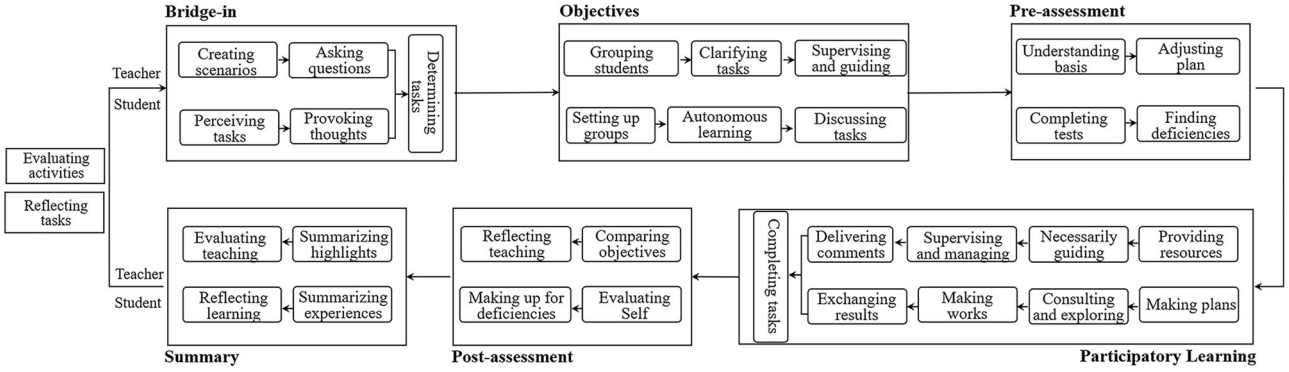

Fig. 2 Schematic diagram showing implementation steps of BOPPPS teaching model activities combined with OBE concept. From the perspectives of both teachers and students, we carried out teaching activities through the six specific steps of the BOPPPS teaching model (Bridge-in, Objectives, Pre-assessment, Participatory Learning, Post-assessment, and Summary) to achieve learning outcomes.

Before class, teachers preloaded typical teaching cases and clinical images of jaundiced patients on the "Xuexitong" platform, posing questions to engage students in the course material. For examples, what clinical manifestations do you find through observation; what are the biochemical mechanisms leading to these clinical manifestations; what disease may a patient suffer from?

Objectives. Based on the graduation requirements and professional training objectives of students, we divided the objectives into three dimensions, further refined them into ability index points. All teaching and learning activities were conducted and developed around the index points and their corresponding learning objectives. The teacher informed students of the learning objectives in the "Notification" column of the "Xuexitong" platform in advance. The students could use the resources of the platform for purposeful independent learning. For example, before class teaching of "Selection and evaluation of clinical biochemistry test methodology" of clinical biochemistry testing course, the students were informed in advance that through this class they would learn to design a technical route for the performance evaluation of a clinical biochemical test method. The establishment of learning objectives would enable students to have a clear understanding of the content of this class, and enhance their motivation to learn, thus more effectively urging students to actively participate in learning and meet the requirements of the index points.

Pre-assessment. Pre-assessment was used to understand the gap between real situation of the students and the index points requirements through questionnaires, exams, homework, questions, discussions, and other forms after the learning objectives were established. The teacher posted a time-limited questionnaire

or test through the "Xuexitong" platform, which covered the basic knowledge related to this class. After finishing the statistics on the students' task completion, the teacher got to know the students' knowledge mastery and the effect of their independent learning before class, so as to achieve reference for subsequent teaching design, such as adjusting the depth and pace of lecture content.

Participatory learning. Participatory learning is a very important part, which facilitates teacher-student interaction to achieve interactive learning of the course's core content. In this link, both student group discussion and interactive communication under simulated situations were arranged to enhance the classroom atmosphere of participatory learning and achieve the real effect of participatory learning between teachers and students. This link could be divided into three sub-parts as follows, including determination of learning tasks, exploration of activities, exchange and display of results:

Determination of learning tasks: Under the guidance of the index points, the teacher clarified what knowledge and skills students should master in this class according to the curriculum standards and teaching objectives, and made it clear to the students what outcomes they should obtain through this class. Then, learning tasks were determined around the outcome goals, and the students were given the space to think and develop independently. For example, since typical cases of diabetes, liver disease, kidney disease, hyperthyroidism, acute myocardial infarction, familial hypercholesterolemia would be selected during the teaching in the clinical biochemistry testing course, the cases and some related questions were published in advance of the "Xuexitong" platform. The inquiries focused on identifying potential diseases, diagnostic foundations, appropriate biochemical tests, and the theoretical underpinnings of test design. The students were asked to consult relevant information and material in advance, perceive the learning tasks in advance in the context created by the teacher, and engage in independent learning to prepare for subsequent class learning.

Exploration of activities: The teacher used the random grouping function in the "Xuexitong" platform to divide students into groups, making each group with 5–7 persons. In the process of activity exploration, students chose the appropriate path according to their respective tasks, independently consulted relevant information and material to complete the corresponding learning tasks, and then deliberated, analyzed and discussed with group members on the specific task content.

Results exchange and display. The OBE Concept emphasizes the importance of providing students with opportunities as many as possible to display their learning results, which can in turn motivate them to learn. A representative was selected randomly to give a presentation about task completion status, and other groups gave their opinions or suggestions, so that they could complement one another. Moreover, the teacher gave the comments and supplements, and summarized all the presentations in the end to provide feedback on the completion of the index points. In this way, all students actively took part in the learning process.

Post-assessment. An assessment was conducted near the end of the class. The targeted assessment was used to check students' learning status and to understand whether students' learning in this class had achieved the index points. The assessment was designed to effectively measure whether index points were achieved, so as to give feedback on teaching and learning. Accordingly, the teaching could be timely and correctly adjusted, thereby getting enhanced effectiveness. After the completion of classroom teaching, assignments were published through the "Xuexitong" platform so that the teaching could further inspect students' understanding and mastery of this section based on the completion status of the exams and assignments.

Summary. The teacher reviewed all the course content of this section, helping students comprehensively understand and systematize the learned content around the index points, and promoting reflection on their own learning effectiveness. The teacher could also use the summary section to emphasize again the key points of this lesson or to set the stage for the next lesson. Summaries are usually brief, but essential. For example, to summarize the lesson "Bilirubin metabolism and the mechanism of jaundice" in the clinical biochemistry testing course, firstly, we outlined the four components of bilirubin metabolism: Mononuclear phagocyte system generation; Transport in blood; Uptake, transformation and excretion by hepatocytes; Changes in the intestinal tract and enterohepatic circulation. Then, the pathogenesis of the three types of jaundice was briefly reviewed in the context of the bilirubin normal metabolism diagram. Additionally, the content of the next lesson was previewed: the laboratory differential diagnosis of the three types of jaundice and the determination of bilirubin. Summaries give students a sense of the systematicness, logicality, and completeness of the course.

Above all, to achieve the index points, the BOPPPS teaching model combined with the OBE concept begins with attracting students' interest in learning. Teaching objectives are announced before class to achieve outcome orientation, and a pre-assessment is performed to understand students' knowledge and ability reserves. Then, based on the results of this assessment, interactive and participatory teaching activities are designed, and students' mastery is assessed through assessments after the completion of teaching activities. Finally, a teaching summary is launched, which is also the introduction to the next class.

The use of diverse assessment methods to measure students' learning effectiveness. The OBE education concept advocates the use of multiple evaluation methods to assess students' learning outcomes, breaking through the traditional way of paper-and-pencil answer-based tests, introducing a diverse assessment model for the entire teaching process, and emphasizing the evaluation of students' overall quality. The evaluation dimensions mainly included examinations and, evaluations from the teachers and other students in the group. The students not only received feedback from teachers and classmates but also had a clear understanding on the mastery of their own knowledge and skills and how they performed during the cooperation with classmates. Learning effectiveness was improved through teacher and classmates' comments as well as personal self-evaluation and reflection. The diverse assessment approach is more reasonable for learning performance evaluation and more conducive to student growth.

Methods

As shown above, we designed a BOPPPS teaching model combined with the OBE concept, and outlined its implementation steps and assessment methods of students' learning effectiveness. Herein, clinical biochemistry testing course was used as a model to assess the effects of the teaching reform. We analyzed whether the BOPPPS teaching model combined with the OBE concept could play a positive role in promoting students' performance and shaping their own ability, so as to promote the continuous improvement of this teaching model, with a view to providing teaching reference for the medical laboratory technology-related

professional courses. Based on the graduation requirements and professional training objectives of students, we divided the course objectives into three dimensions, further refined them into 10 index points. Finally, the validity of the model was verified using diverse assessment, questionnaires, and interviews. The chapter "Biochemical tests of endocrine diseases" was used as an example for showing the implementation process.

Ethics statement. This study was approved by the Ethical Review Committee of Hebei North University (No. hbnuky-2022-066). All participants voluntarily participated in this study and completed an informed consent form. Information with the potential to identify individuals was anonymized.

Experimental design

Experimental subjects. Seven undergraduate classes from the Medical Laboratory Technology program at Hebei North University participated in this study. Each class contained 36 or 37 students. Among them, three classes were randomly selected as BOPPPS group, for which the BOPPPS teaching model combined with the OBE concept was implemented. The other four classes were set up as traditional group, for which the traditional teaching model was implemented. The students in different classes had no significant difference in terms of age and gender. Especially, At the beginning of the study, all the students have been assessed for their learning abilities and critical thinking skills, which were assessed based on students' GPA (Ghanizadeh, 2017; Kim and Shin, 2021; Nur'azizah et al., 2021) during last two years and statistical analysis. The results showed that there was no significant difference in critical thinking skills and learning abilities of students in the traditional group and those of students in BOPPS group. The traditional teaching model adopted a teacher centered teaching method, emphasizing the teaching of teachers and the listening of students. At the beginning, the students were randomly divided into groups. The student number of each group was the same as that of BOPPPS group. The teaching process included three parts as follows: (1) teacher lecture (55 min), during which teachers systematically explained new knowledge, concepts, principles and skills. (2) practice and Q&A (25 min), during which the students engaged in case studies and discussion in groups, and the teacher answered students' questions. (3) summary and preview assignment (10 min), during which the teacher summarized the lesson, emphasized key points, and finally assigning preview tasks for the next class.

The teaching team were provided with unified training on the teaching model to ensure that every teacher utilized the same teaching methods and strategies, and that the students in each group received consistent teaching methods.

Analysis of outcome targets and index points. According to result-oriented requirements of the OBE concept, in this study the outcome objectives of the course "Clinical Biochemistry Testing" were divided into knowledge objectives, competence objectives and quality objectives, and further subdivided into 10 index points corresponding with the training objectives and graduation requirements of medical laboratory technology students, which were shown in Table 1.

Corresponding relationship between the teaching content and index points. Each chapter of the clinical biochemistry testing course corresponds to the corresponding index points to form a matrix of teaching activities to ensure that the course teaching outcomes support graduation requirements, as shown in Table 2.

Teaching of the example chapter. Endocrine system is an important regulatory system in the body. Secreted hormones enter the blood circulation and regulate the normal physiological activities of many organs and cells through body fluids. The content of this chapter is highly theoretical, numerous and complex. Before class, according to the teaching model, the teacher published learning objectives, learning tasks and learning resources through the "Xuexitong" platform the day before class teaching. The teacher adjusted the classroom teaching content appropriately according to the results of pre-assessment at the beginning of the class. Then, the students learned by means of question guidance, group discussion and representative presentation, and the teacher comprehensively controlled the teaching and learning effect and rhythm through the teaching model. After class, the teacher posted the summary of learning effect and homework online, and collected students' learning feedback. According to the feedback, the learning difficulty and rhythm of the following chapters were adjusted, and finally the diverse evaluations were carried out. The teaching process of this chapter in the class of 90 min is shown in Fig. 3.

Analysis of teaching effect

Questionnaire for survey. A survey was conducted to exhibit the effectiveness of the BOPPPS teaching model combined with the OBE concept and traditional teaching methods. The questionnaire was formulated based on the expected outcomes. Table 3 showed the questionnaire survey form. For each question, responses of the students were given out of five options, including "strongly disagree", "disagree", "neutral", "agree" and "strongly agree". The questionnaire covered three aspects as follows: 1) student outcomes; 2) course outcomes; 3) teaching methodology. Student outcomes mainly manifested the students' skills and the ability to utilize them in future professional life. Course outcomes represented the students' opinions about some aspects of the course, mainly including its precision, workload, attraction, and help. The last part of the questionnaire was about the teaching methodology, which is also very important because it directly affects student learning. The teaching methodology and the teacher should exhibit some necessary characteristics (Ezechil, 2017), such as presenting knowledge and information clearly, treating the students with respect and fairly, enthusiastic about teaching the course, encouraging the students to learn, and providing supports and help timely when needed.

Student score analysis. In order to further quantitatively compare the teaching effect of the BOPPPS teaching model combined with the OBE concept and traditional teaching methods, we conducted systematic analyses into scores of the BOPPPS group and traditional group at end of both the chapter (staged scores) and the semester (final scores). We have considered two aspects for both the stage scores and final scores. One aspect is the examination scores. The other aspect is diverse assessment scores, among which examination, evaluation from teachers and classmates accounted for 50%, 30%, and 20% respectively. The scores of the BOPPPS group and traditional group were expressed as mean value ± standard deviation. Statistical calculations were conducted with SPSS (Chicago, IL, USA) 21.0 Windows software, and T-test was used to analyze the differences of the scores between the two groups. A p-value less than 0.05 was regarded as a significant difference. Moreover, we compared the proportion of students in different score intervals (90–100, 80–90, 70–80, 60–70 and under 60) in the two groups.

Table 1 Corresponding relationship between course objectives and index points.

Course objectives	Index points supporting graduation requirements
A-Knowledge	A-1: To acquire basic theoretical knowledge of clinical biochemistry testing and understand the structure and function of the human body and normal physiological state in all stages of life. A-2: To master the clinical application of laboratory test items and testing methods and results for various common diseases and major diseases.
B-Ability	B-1: To master the commonly-used techniques of clinical biochemistry testing, possess test operation ability and clinical laboratory management ability. B-2: To master the basic structure and performance of commonly used medical testing instruments, possess the ability to use and maintain conventional instruments. B-3: To develop logical thinking ability and critical thinking ability through problem guidance and case studies. B-4: To develop communication, expression and team-cooperation abilities through teamwork. B-5: To develop independent learning and lifelong learning abilities through independent inquiry and exploration.
C-Quality	C-1: To recognize professional responsibilities and social missions, and establish a professional ideal of serving human health. C-2: To establish the concept of lifelong learning, recognize the importance of continuous self-improvement, and continuously pursuing excellence. C-3: To possess scientific attitude and innovation sense.

Table 2 Corresponding relationship between teaching content and index points.

Teaching content	A-1	A-2	B-1	B-2	B-3	B-4	B-5	C-1	C-2	C-3
Enzymatic assay technology	√	√		√	√			√	√	√
Automated Biochemical Analysis Technology	√	√	√	√		√	√		√	
Biochemical tests of plasma proteins and nitrogen-containing compounds		√	√		√		√	√		√
Biochemical tests for disorders of glucose metabolism	√	√	√			√	√		√	
Biochemical tests for disorders of plasma lipoprotein metabolism	√	√		√	√	√	√	√		
Biochemical tests for disorders of electrolyte and acid-base balance	√	√	√		√		√	√	√	
Biochemical tests of enzymes in body fluids	√	√	√		√	√			√	√
Biochemical tests for hepatobiliary diseases	√	√	√	√		√		√		
Biochemical tests for kidney diseases	√	√	√		√	√	√			√
Biochemical tests for cardiovascular diseases	√	√	√	√	√	√	√			
Biochemical tests for disorders of bone metabolism and related elements	√	√	√	√		√	√	√	√	
Biochemical tests for endocrine diseases	√	√			√	√	√		√	√
Biochemical tests for pregnancy and newborns		√	√	√	√		√	√		√

Interview record analysis. In order to understand views and learning experience of the teachers and students who participated in the experiment about the BOPPPS teaching model combined with OBE concept, we conducted oral interviews with them, which were launched after the final exam and before the students received their scores. The interviews were held by teaching supervision group of the college who had no dependent relationship with the teachers and students of this course. Ten students were randomly selected from each class in the traditional group and BOPPPS group by a simple random sampling method. The conversation with students mainly included students' acceptance and adaptation to the teaching mode, their learning effectiveness and difficulties encountered, opinions and suggestions on the teachers, cooperation in the group, and their feelings towards the classroom environment. All the teachers were interviewed. The conversation with the teachers mainly included the overall feeling of the teachers towards the BOPPPS teaching mode and whether they have adapted and liked this teaching mode; their experience in the BOPPPS teaching mode, including course design, teaching methods, and the use of teaching resources; changes in teacher-student interaction and classroom atmosphere under the BOPPPS teaching mode; the mastery of knowledge by students in the traditional and BOPPPS teaching mode; the advantages and disadvantages of BOPPPS teaching mode compared to traditional teaching mode. Finally, the teaching supervision group checked each feedback, extracted key information and viewpoints, and summarized the feedback and suggestions.

Results

Questionnaire survey. Each student of both BOPPPS group and traditional group was asked to fill out the questionnaire form and record their responses to every item in the questionnaire. All of the filled questionnaire forms were collected. Figure 4a showed the responses of the BOPPPS group while Fig. 4b shows the survey result of the traditional group. Quantitative analysis results of the student responses based on that "strongly disagree", "disagree", "neutral", "agree" and "strongly agree" were set as 1, 2, 3, 4, and 5, respectively, were shown in Fig. 4c. It could be found that compared with the students in traditional group, more students in BOPPPS group thought that they developed analytical approach, elevated problem-solving skills and produced new ideas, and that the developed skills were helpful for their future career. In addition, compared to the traditional group, higher proportion of students in BOPPPS group believed that technical approaches were adopted, and that application of knowledge to practical work was learned. From the responses to the second part of questionnaire, course outcomes, it could be seen that in contrast to the traditional group, more students in BOPPPS group agreed that the skills were helpful for their future professional development. Moreover, higher proportion of students exhibited a keen interest in the course, and thought that the course materials were updated and relevant. The last portion was related to the teaching methodology. Compared with the students in traditional group, more students in BOPPPS group agreed that knowledge and information were presented clearly, and that learning and participation were well encouraged.

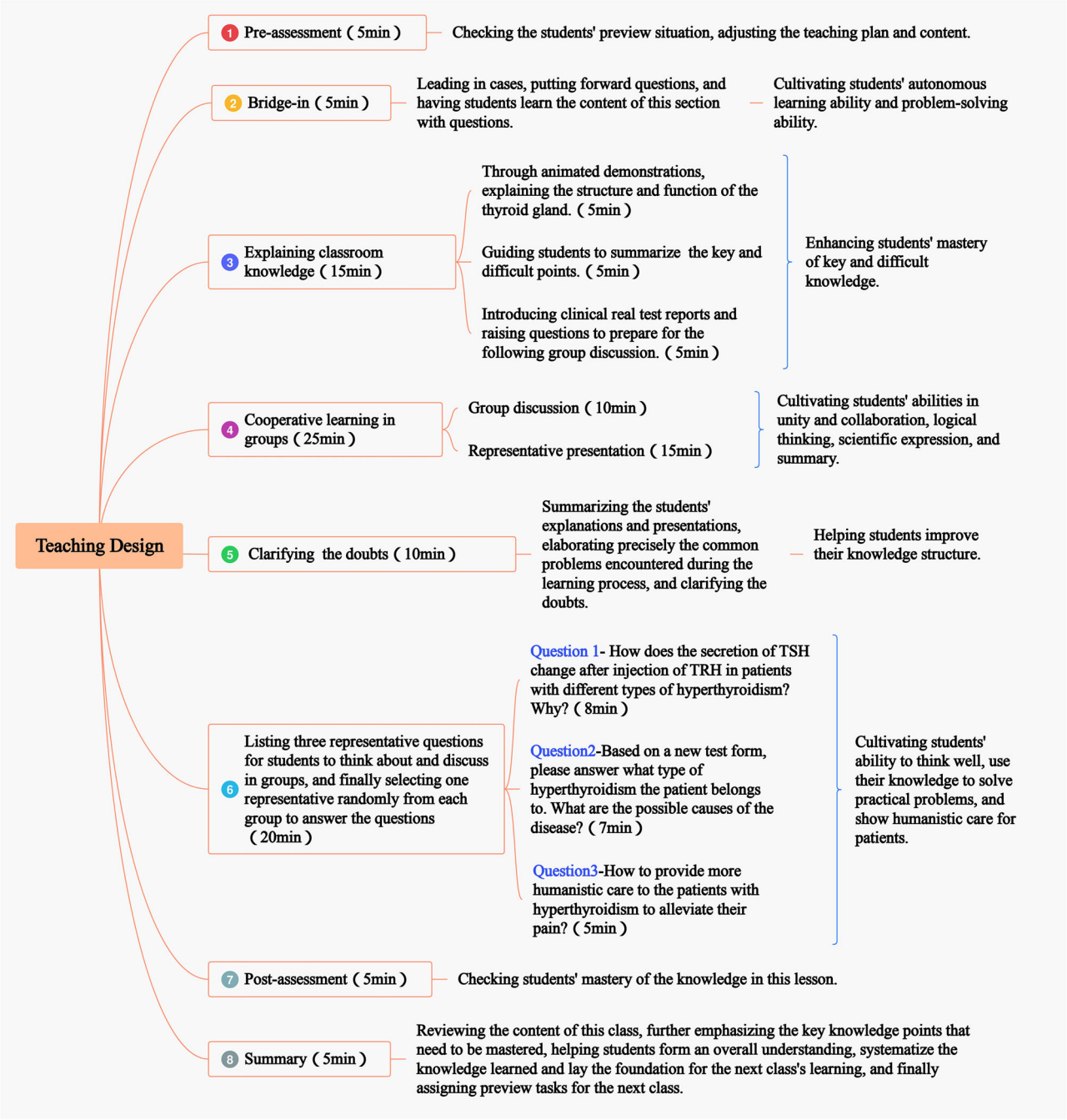

Fig. 3 Schematic diagram showing teaching process of the chapter "Biochemical examination of endocrine diseases" in the class of 90 min using the BOPPPS teaching model combined with OBE concept. In the class, the first step is to conduct a pre-assessment to understand the students' preview situation, and adjust the teaching content appropriately. Next, cases were led in and questions were put forward to attract students' attention and guide them into a learning state. Then, the students were engaged in a series of participatory learnings, including group discussions and representative statements after the teacher explained knowledge points through animated demonstrations and clinical real test reports, and further thinking and discussions based on the summary and questions of the teacher. And then, a post-assessment was conducted to evaluate the learning effectiveness of students. Finally, the teacher summarized the key content of this lesson.

95.42% of the students in BOPPPS group agreed that the course was well taught, including 62.39% of those who strongly agreed, while 84.25% of the students in traditional group agreed that the course was well taught, including only 36.3% of those who strongly agreed.

Statistical mean of the student responses to the six questions in each section of the questionnaire survey based on that "strongly disagree", "disagree", "neutral", "agree" and "strongly agree" were set as 1, 2, 3, 4, and 5, respectively, was depicted in Fig. 4d. It was shown clearly that for the part of student outcomes, the BOPPPS group had a generally higher level of agreement than the traditional group did. For the part of course outcomes, the level of agreement for the BOPPPS group was also significantly higher than that for the traditional group although two groups of students with almost the same proportion agreed that the workload of the course was manageable. For the last part of questionnaire survey, the BOPPPS group also had a significantly higher level of agreement than the traditional group did. The data

Table 3 Questionnaire for evaluating the expected outcomes.

Outcome type	Number	Items
Student outcomes	i	Analytical skills were elevated after completion of the course.
	ii	Problem-solving skills were enhanced after completion of the course.
	iii	At least one technical approach was adopted after completion of the course.
	iv	Application of knowledge to practical work was learned after completion of the course.
	v	New ideas and assistance were produced after completion of the course.
	vi	The developed skills are helpful for future career.
Course outcomes	vii	The course was equipped with skills, which are helpful for future professional development.
	viii	The course materials were updated and relevant.
	ix	The course was well coordinated.
	x	The course was academically rigorous.
	xi	The interest in the course has been developed.
	xii	The workload of the course was manageable.
Teaching methodology	xiii	The course was well taught.
	xiv	Learning and participation were always encouraged.
	xv	Knowledge and information were presented clearly.
	xvi	The students were treated with respect and fairly.
	xvii	The teacher was enthusiastic about teaching the course.
	xviii	The teacher could aid and feed back timely when needed.

further confirmed the potency of the BOPPPS teaching model combined with the OBE concept in education.

Furthermore, we conducted reliability analysis to evaluate reliability of the questionnaire. The higher the Cronbach α coefficient is, the higher the reliability is. If the coefficient were above 0.7, reliability of the questionnaire would be acceptable while if the coefficient were below 0.6, reliability of the questionnaire would be too low, and its items would need to be redesigned (Hair et al., 2011). The reliability analysis result of the questionnaire in this study was shown in Table 4, from which it could be seen that the Cronbach reliability coefficient was greater than 0.9, indicating that the reliability of the data should be very high.

In addition, we conducted validity analysis using Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity (BTS) to evaluate if the questionnaire could effectively measure the required content and express the accuracy of the results. The results showed that the KMO value of our questionnaire was 0.965 and that the *P* value of BTS was 0.000 (Table 4), which indicated that our questionnaire had good structural validity (Kline, 2015).

Student score analysis

Staged score. After the teaching of the chapter, student staged scores of the BOPPPS group and traditional group were analyzed. Figure 5a shows that the examination scores of the BOPPPS group (88.7 ± 5.8) were significantly higher than those of the traditional group (78.9 ± 5.8). Moreover, diverse assessment scores of the BOPPPS group (90.4 ± 5.3) were also notably higher than those of the traditional group (77.7 ± 5.1). The difference between the two group diverse assessment scores was much bigger than that between the two group examination scores. Specially, we analyzed the score interval of the BOPPPS group and traditional group, the results of which were shown in Fig. 5b. The percentage of 90–100 score interval students in the BOPPPS group was much bigger than that in the traditional group (examination: 49.5% vs. 8.9%; diverse assessment: 68.8% vs. 2.1%), while the percentage of students, whose scores were under 80, in the BOPPPS group was much smaller than that in the traditional group (examination: 7.3% vs. 52.1%; diverse assessment: 9.2% vs. 65.8%). Especially, there was no student under 60 score in the BOPPPS group while there were some in the traditional group (examination: 0.7%; diverse assessment: 1.4%).

Final score. At the end of the semester, the final scores of both BOPPPS group and traditional group were analyzed. Firstly, the final examination scores of the two groups were compared, as shown in Fig. 6a. We can see that the final examination scores of the BOPPPS group were significantly higher than those of the traditional group (90.7 ± 5.7 vs. 80.3 ± 5.4). Besides, the diverse assessment scores of the BOPPPS group were also significantly higher than those of the traditional group (91.7 ± 5.5 vs. 78.0 ± 5.9). Obviously, the difference in the diverse assessment scores between the two groups was much bigger than the difference in examination scores between the two groups. Furthermore, the score interval of the BOPPPS group and traditional group was summarized, the results of which were shown in Fig. 6b. We can see that the percentage of 90–100 score interval students in the BOPPPS group was much bigger than that in the traditional group (examination: 51.4% vs. 6.2%; diverse assessment: 74.3% vs. 3.4%). As expected, the percentage of students with scores under 80 in the BOPPPS group was much smaller than that in the traditional group (examination: 5.5% vs. 41.1%; diverse assessment: 7.3% vs. 63.0%). Moreover, there were no students under 60 score in the BOPPPS group while there were some in the traditional group (examination: 0.7%; diverse assessment: 0.7%).

Interview record analysis

Interviews with the teachers. The teachers stated that compared to the traditional teaching, the BOPPPS teaching model provided a more clear teaching framework, making classroom teaching more organized and helping them better organize and plan teaching content. The BOPPPS teaching model made the classroom more lively and interesting, and students show higher enthusiasm. The teachers generally believed that through interactive activities such as group discussions and representative presentations, students' interest in learning could be enhanced, and their ability to analyze and solve problems could be exercised. In the BOPPPS teaching model, multimedia and online resources could be more fully and effectively utilized, enriching teaching content and methods. The teachers thought that in the BOPPPS teaching mode, teacher-student interaction was more in-depth, the classroom atmosphere was more active, students were more willing to speak and ask questions, and the communication and interaction between teachers and students increased the fun and attractiveness of the classroom, as well as improved students' understanding and

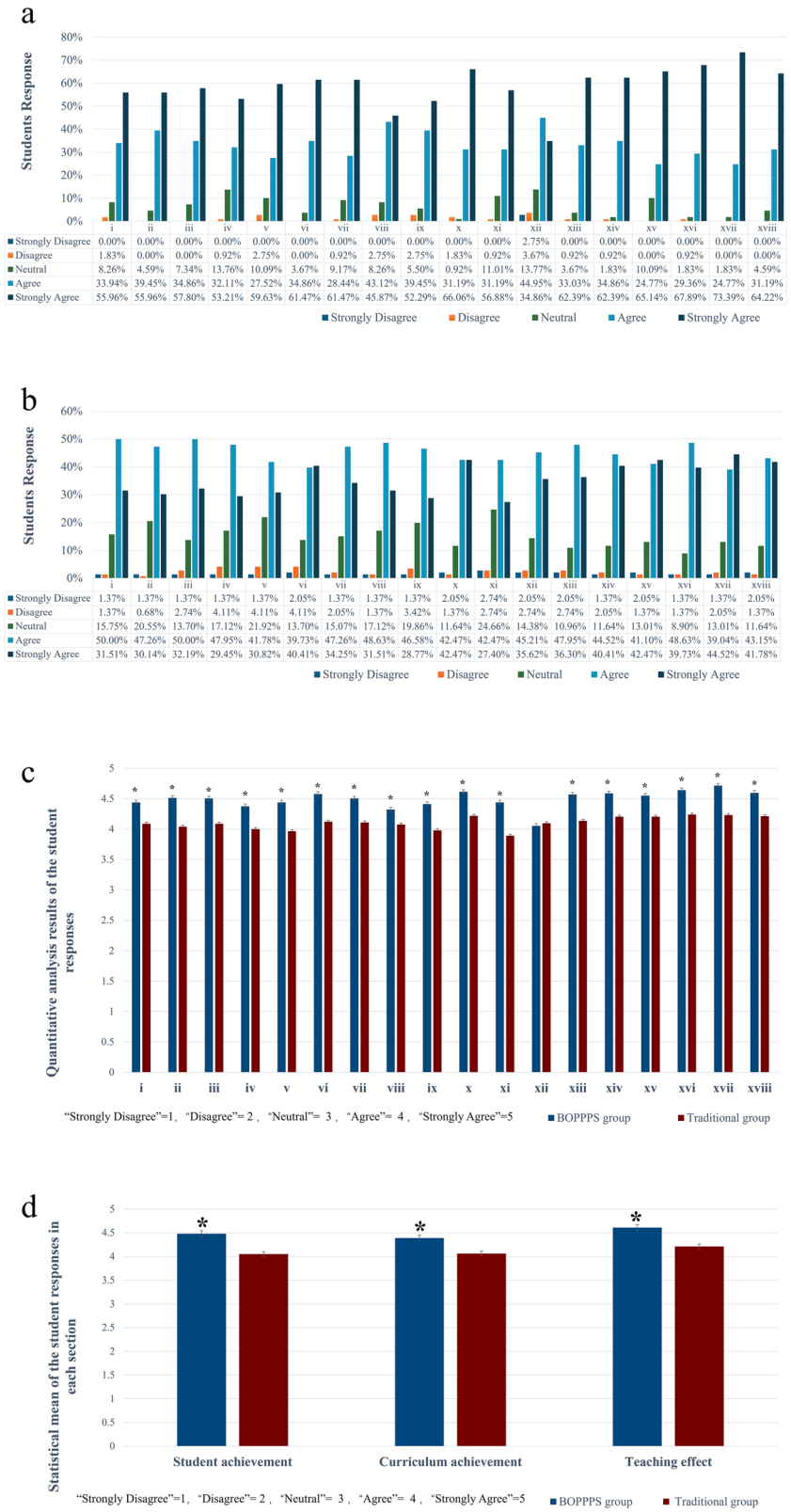

Fig. 4 Analysis results of teaching effect based on the questionnaire survey. Student responses of BOPPPS group (**a**) and traditional group (**b**) to each question of the questionnaire survey, which were given out of five options, including "strongly disagree", "disagree", "neutral", "agree" and "strongly agree" for each question; Quantitative analysis results of the student responses (**c**) based on that "strongly disagree", "disagree", "neutral", "agree" and "strongly agree" were set as 1, 2, 3, 4, and 5, respectively; Statistical mean of the student responses to the six questions in each section of the questionnaire survey (**d**) based on that "strongly disagree", "disagree", "neutral", "agree" and "strongly agree" were set as 1, 2, 3, 4, and 5, respectively. (* denotes $P < 0.05$ compared to traditional group).

memory of knowledge. Moreover, the teachers reported that compared to the traditional teaching, the BOPPPS teaching model could make students have a stronger grasp and improved understanding and application abilities of knowledge because they have more opportunities to participate in the exploration and understanding process of knowledge.

Table 4 Reliability and validity analysis results of the questionnaire.

Analysis type	Results
Reliability	Cronbach's α coefficient: 0.970
Validity	Kaiser-Meyer-Olkin value: 0.965
	P value of Bartlett's Test of Sphericity: 0.000.

Interviews with the students. The students in the BOPPPS group said that they liked such a learning atmosphere, which could improve their interest in learning, and cultivate their teamwork ability and innovative thinking. The achievement-oriented approach enabled them to know clearly "what to learn, how to learn, and to what extent they need to learn". Moreover, they could always check their achievement of learning objectives in class and get timely feedback information. Communication and discussion among classmates were found to not only increase knowledge but also foster mutual understanding and positive emotions. Although a small number of students expressed that they were initially not accustomed to this teaching mode, they felt that their knowledge and ability had been significantly improved and gained a lot, and now they gradually become fond of this teaching mode, and even expect more courses to adopt this teaching mode in future.

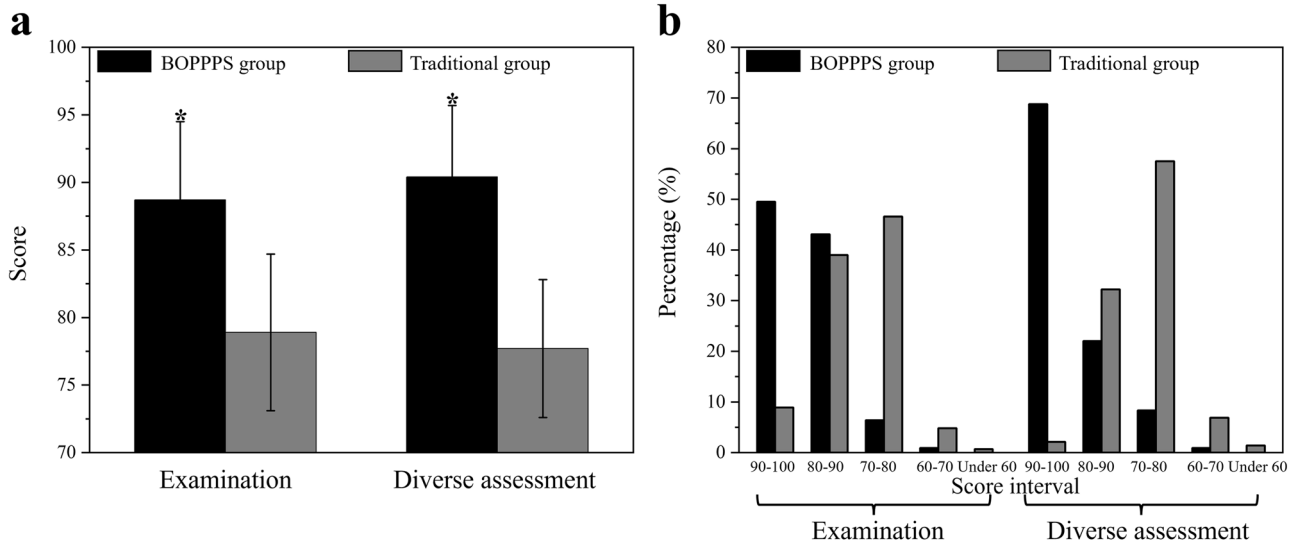

Fig. 5 Student score analysis results of the "Biochemical examination of endocrine diseases" chapter. Examination score and diverse assessment score among which examination accounted for 50%, evaluation from teachers accounted for 30%, and evaluation from classmates accounted for 20% (**a**), and percentage of the students in different score interval (**b**). (* denotes $P < 0.05$ compared to traditional group).

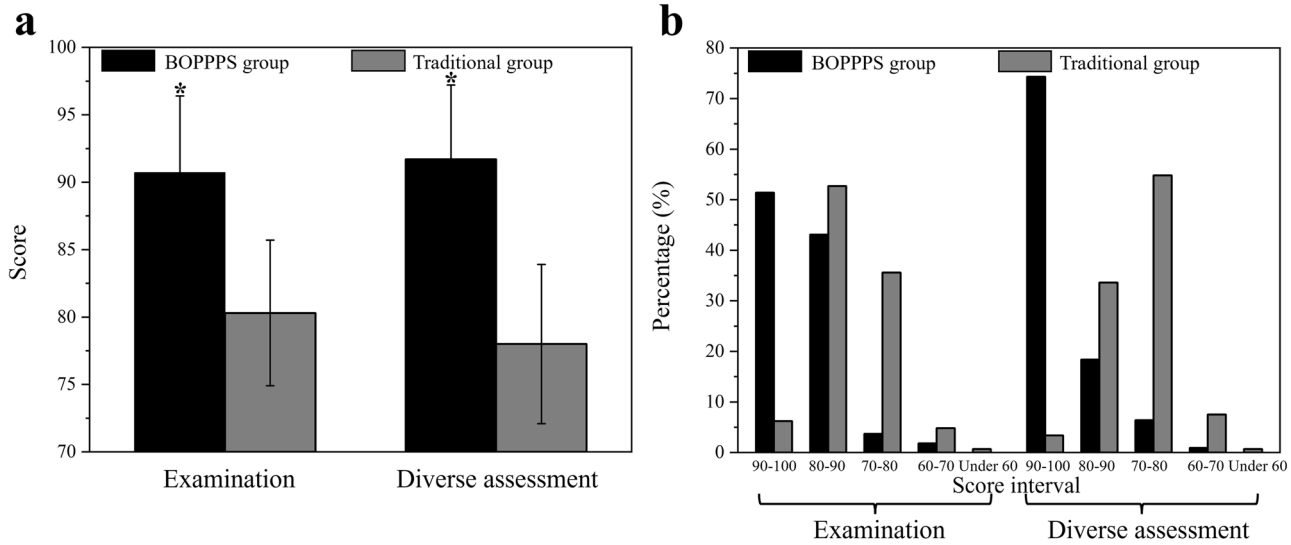

Fig. 6 Student score analysis results of the course. The final examination score and diverse assessment score among which examination accounted for 50%, evaluation from teachers accounted for 30%, and evaluation from classmates accounted for 20% (**a**), and percentage of the students in different score interval (**b**). (* denotes $P < 0.05$ compared to traditional group).

Traditional group students felt that the classroom was dull and lacked interaction, but they became accustomed to the traditional teaching mode and were able to learn according to the teacher's guidance. However, they thought that their critical thinking and innovative abilities had not be significantly enhanced. The students generally believed that the teachers were serious and responsible, but they hoped that the teachers could increase the interactivity and fun of the classroom. They felt that cooperation among students was not enough.

Discussion

The knowledge system of teaching content needs to be dynamically updated according to the frontiers and tendencies of the discipline and the requirements of social development, and introduce the new achievements of academic and scientific development of the discipline into the curriculum to meet the professional requirements of modern technology. The BOPPPS teaching model emphasizes student-centered learning and embodies specific implementation process, which has played an important role in improving the attractiveness of classroom teaching. However, there are still problems in its implementation, such as insufficient targeting of activity goals towards social demands, unclear teaching objectives, etc., resulting in limited teaching effectiveness, and the students could not be well recognized by employers after graduation (Wu et al., 2022; Shen et al., 2024). OBE emphasizes result-oriented education or goal-oriented education and has made significant contributions to education systems worldwide. However, OBE did not show how to implement the teaching process (Yang et al., 2023; Huang et al., 2023). We can see that the two teaching models are complementary. Although they have been extensively practiced respectively, few studies on the combined use of them have been found. In this study, we designed the BOPPPS teaching model based on the OBE concept. Under this model, the emphasis is very much on clarifying objectives, embodying specific implementation process, and evaluating learning progress and completion. Especially, we proposed specific index points according to results-oriented requirements of the OBE concept and the professional training objectives. Teaching content was constructed according to the index points, and the theoretical, practical, high-level and innovative nature of the curriculum were specifically reflected according to the employment destination and graduation requirements of students. We transformed the curriculum teaching from one-way knowledge teaching to two-way discussion between teachers and students through the BOPPPS teaching mode, keeping the teaching content up-to-date with the times. Moreover, comprehensive and reasonable evaluations including both phased assessments and summative assessments at the end of the course were suggested, such as phased exams, final exams, student evaluations, teacher evaluations, questionnaire surveys, student interviews, teacher interviews, etc.

During the teaching implementation process, we reasonably arranged teaching content, and chose teaching methods and means based on the index points to ensure high-quality teaching. The teaching methods were more diverse, and information and digital teaching tools were more complete. We have recorded 35 teaching videos, each of which lasts 10–15 min and focuses on one knowledge point for students to learn online. Through teacher guidance, students developed learning plans based on learning tasks and objectives, using textbooks, electronic courseware, exercise library and case library, to clarify learning objectives and master course content well. The six links of the BOPPPS teaching model were gradually integrated and organically combined to create a closed teaching loop. The purpose of creating such a teaching loop was to enable students to form a continuous "ubiquitous learning", which could extend our classroom beyond the original classroom, make the teaching process interactive and immersive, and effectively solve the problem of low participation of extracurricular student in learning, greatly improving students' learning enthusiasm and enhancing their sense of gain (Dai et al., 2022; Hu et al., 2022; Zhang et al., 2020). In addition, through three-dimensional and systematic learning before, during, and after class, knowledge learned by students was consolidated, and their habit of discovering problems and exploring independently was gradually developed, forming a virtuous cycle of high-level learning, which is greatly beneficial for the learning and development of subsequent courses and the improvement of their own quality (Chen et al., 2022; Z. Li et al., 2023b).

Because of the results-oriented OBE concept education, students achieved a clearer understanding of the employment situation and graduation needs. Targeted learning exercises have improved practical skills and clinical thinking abilities of the students, and their overall quality has significantly improved. The teaching staff of the internship and training hospital reported that the knowledge structure of these students was more reasonable and their overall quality was high. The student evaluation excellence rate for the teaching team reached 100%, and the average score of the team members reached higher than 95 on a 100-point scale. At the same time, both theory and practice were emphasized. The teaching models that emphasized practical application have been unanimously recognized by students and colleagues (Chung et al., 2015; S. Li et al., 2023a; Li et al., 2015).

During the teaching implementation process, we realized that the BOPPPS teaching model combined with the OBE concept should be flexibly applied, following the basic framework of BOPPPS, but not rigidly adhering to the fifteen minutes and six small modules. Normally, the BOPPPS teaching mode divides a class into six small modules, each of which lasts for fifteen minutes. These small modules serve as a connecting link to form a closed-loop teaching mode. But in the actual teaching process, there are many unpredictable factors, and the time of each process will inevitably be longer or shorter. Fifteen minutes is only an ideal situation, so in practice, teachers should plan the class reasonably based on the actual situation. At the same time, the six small modules in teaching do not necessarily need to be carried out in the original order one by one. The modules can be appropriately merged and reorganized according to the teaching content, such as combining bridge-in with objectives for teaching, or organically combining objectives with pre-assessment.

Conclusions

This study developed a BOPPPS teaching model combined with the OBE concept for higher education. First, the course outcome goals were divided into three dimensions – knowledge, ability and quality, and further specified into index points. Then, the teaching content of each chapter was set to correspond with the index points. Finally, the BOPPPS teaching model was used to meet each requirement. The effectiveness of this teaching model was assessed in the clinical biochemistry course. According to the training objectives and graduation requirements of the medical laboratory technology major, the results-oriented objectives of clinical biochemistry testing course were divided into three dimensions and subdivided into 10 index points. The content of each chapter corresponded to the index points one by one, ensuring that each index point was supported during teaching, enabling students to always focus on the expected results in learning, and letting them know what to learn, how to learn, and to what extent they have learned. Under the teaching model, the students could self-reflect on the achievement of their learning and ability development goals better, and be promoted better to internalize the clinical biochemistry testing knowledge. The results showed that the teaching quality was significantly enhanced by the teaching reform. Overall,

compared to the traditional teaching method, the BOPPPS teaching model combined with OBE concept possesses clearer objectives, could stimulate students' learning motivation better, and stimulate their learning interest and enthusiasm better. Moreover, evaluation methods used in the teaching model are reasonable and diverse, and could assess the comprehensive abilities required by today's society. So, the BOPPPS teaching model combined with OBE concept could provide an effective strategy for teaching reform and improvement of higher education.

Data availability

The baseline data, questionnaire survey results, stage scores, and final scores of students collected and analyzed during the current study are available in the Harvard Dataverse repository: https://doi.org/10.7910/DVN/RJZQCD.

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Author contributions

Zhiwei Xu: Conceptualization, methodology, investigation, writing - original draft preparation, writing—review and editing, funding acquisition, and resources; Liping Ge: Data curation, formal analysis, and investigation; Wei He: Data curation, writing—original draft preparation, and writing—review and editing; Guiqin Song: Methodology, formal analysis, and investigation; Jie Liu: Data curation, formal analysis, and investigation; Lijuan Hou: Data curation and investigation; Xiaoyun Zhang: Data curation and investigation; Xiaotong Chang: Data curation and investigation; Lan Yin: Conceptualization and writing - review and editing; Xiaoming Li: Conceptualization, methodology, writing—original draft preparation, writing—review and editing, funding acquisition, resources, and supervision.

Competing interests

The authors have no competing interests.

Ethics approval

This study was approved by Ethical Review Committee of Hebei North University (No. hbnuky-2022-066). All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national

research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all participants who took part in the experiment from May 2022 to May 2023. All participants voluntarily participated in this study and completed an informed consent form. Informed consent was obtained from all participants before the study was launched. Information with the potential to identify individuals was anonymized. We informed each participant of the purpose of the study, their rights, and to safeguard their personal information.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-024-03519-y.

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