Assessment of the Effectiveness of BOPPPS-Based Hybrid Teaching Model in Physiology Education

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Research Article

Keywords: BOPPPS, hybrid teaching, online teaching, Physiology education, teaching model

Posted Date: September 8th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-632675/v1>

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Version of Record: A version of this preprint was published at BMC Medical Education on March 30th, 2022. See the published version at <https://doi.org/10.1186/s12909-022-03269-y>.

Abstract

Background: Online teaching has become increasingly common in higher education, of the post-pandemic era. While a traditional face-to-face lecture or offline teaching remains very important and necessary for students to learn the medical knowledge systematically, guided by the BOPPPS teaching model, combination of online and offline learning approaches has become an unavoidable trend for maximizing teaching efficiency. However, in physiological education, the effectiveness of a combined online teaching and offline teaching model remains poorly assessed. The present study aims at providing an assessment to the hybrid teaching model.

Methods: The study was performed among undergraduate medical students of Class 2017-2019, taught during 2018-2020, in the Physiology course in Harbin Medical University. Based on established offline teaching model with BOPPPS components in 2018, we incorporated online teaching contents into it to form a hybrid BOPPPS teaching model (HBOPPPS, in brief), preliminarily in 2019 and completely in 2020. The effectiveness of the HBOPPPS was assessed by comparing the final examination scores of both objective (multi-choice and single answer questions) and subjective (short and long essays) questions between different classes.

Results: The final examination score of students in Class 2019 (83.9 ± 0.5) who were taught with the HBOPPPS was significantly higher than that in Class 2017 (81.1 ± 0.6) taught with offline BOPPPS and in Class 2018 (82.0 ± 0.5) taught with preliminary HBOPPPS, which was mainly reflected in the average subjective scores. The subjective scores of Class 2019 (41.6 ± 0.3) and Class 2018 (41.4 ± 0.3) were significantly higher than that of Class 2017 (38.2 ± 0.4). In the questionnaire among students in Class 2019, 86.2% of students were satisfied with this HBOPPPS and 79.4% students thought HBOPPPS improved their learning ability. In addition, majority of the students (73.5%) believed that reproducibility of the learning content was the major advantages of the HBOPPPS and 54.2% of the students also appreciated the flexibility of HBOPPPS. Lastly, 61.7% of the students showed a preference to be taught with the HBOPPPS in future.

Conclusions: HBOPPPS is an effective teaching modal and useful for enhancing effectiveness of Physiology teaching. This is attributable to the reproducibility and flexibility as well as the increased students' learning initiatives.

Background

With the development of science and technology, web-based e-learning has been well developed in medical education, especially in 2020 when social distancing to restrain the COVID-19 pandemic caused suspension of classroom teaching in all educational institutions [1, 2]. Classically, web-based learning like video lectures [3–5] mainly serves as supplements for offline lecture and is less effective in resolving individual specific difficult problems, inspiring students' enthusiasm for learning and matching the course objectives tightly. During the COVID-19 pandemic, online teaching largely duplicates the model of

classical offline teaching by introducing the functions of screen share, checking attendance, “raising hands” and “quizzes”, etc.[6], which become more effective due to spatiotemporal efficiency[7, 8], [9].However, some disadvantages inherent for the online teaching are also obvious, such as lack of enthusiasm of students’ participation in addition to some network connectivity issues [8], [9]. Thus, a hybrid teaching method that combines online and offline teaching advantages is highly demanded in the post pandemic era [10], [11], [12].

In modern medical education, a BOPPPS teaching theory has been applied extensively in offline teaching. The BOPPPS is composed of six elements including bridge-in, learning objectives and outcomes, pre-assessment, participatory learning, post-assessment and summary. It was first introduced by Douglas Kerr from the University of British Columbia, and has been developed recently in medical education in China [13–15]. The BOPPPS is considered as a tool to help teachers organize their teaching process clearly and inspire the students' initiatives to learn actively[13]; however, the time limitation of offline teaching makes it difficult for fully applying all the elements, particularly pre- and post-assessments, summary and timely feedback of the learning efficiency. In addition, it is relatively weak in enriching students’ knowledge, establishing feed-forward connections between students and teachers, and targeting general obstacles and meeting diverse learning style preferences among medical students [16]. Thus, incorporating online teaching into the BOPPPS and optimizing its individual components should be tried.

To resolve this issue, in teaching Physiology for medical students in Harbin Medical University, we designed a new teaching modal based on our understandings of learning characteristics of medical students [17]. Physiology is an important discipline in medical education and the bridge between basic medical sciences and clinical medicine study. Efficiency of using such a hybrid teaching model in Physiology education has not been fully assessed. Thus, optimally incorporating online teaching into offline BOPPPS model is important for Physiology education. This new model incorporated online teaching into BOPPPS model that was optimized with some components of TESOT that puts stress on resolving the learning obstacles in global medical education in an active learning [16], to form a new hybrid teaching model, i.e. HBOPPPS. We first performed the hybrid teaching on Physiology in the fall of 2019 for the students of Class 2018, and then in 2020 for Class 2019. The efficiency of this new model was evaluated by the final examination scores which were compared to that from Class 2017 that was taught with BOPPPS only in 2018. A questionnaire was then applied among students of Class 2019 to investigate students’ learning abilities and their assessment of the HBOPPPS.

Methods

Study subjects

This study included 1576 students of clinical medicine major from 3 academic calendar years, i.e., 532from Class 2017, 526 from Class 2018and 518 from Class 2019in Harbin Medical University in China. Six teachers taught Physiology through 80 sessions (45 minutes/session) for all of the students in their

second school year in 2018, 2019 and 2020 respectively. Class 2017 was used as the control group by using the traditional offline (face-to-face) teaching method with BOPPPS (Table 1). We first incorporated the online teaching method into the offline teaching of the students of Class 2018 in the fall of 2019, mainly by posting micro-video lectures on line without considering TESOT components. We further improved the HBOPPPS teaching model in teaching students of Class 2019 by including online guidance of the ongoing lectures and by adding a pre-quiz at the beginning and quizzes and students-led summary at the end of the lecture used in TESOT [16] as the final model of HBOPPPS.

Table 1
Constitution of BOPPPS

BOPPPS	Mode
Bridge-in	A course contents-associated video or image was presented to attract students' attention
Objective/ Outcomes	What the students will gain from the lecture, i.e., the knowledge, emotion and moral education
Pre- assessment	Multi-choice questions or topics for discussion at the first 5 min in the lecture
Participatory learning	Group discussions, student presentations
Post-assessment	Single/multiple choices questions, discussions
Summary	Synopsis explained by teachers

HBOPPPS

HBOPPPS was designed by incorporating online teaching into the enriched BOPPPS components as a hybrid teaching method. HBOPPPS model was applied through the following three stages (Fig. 1 and Supplemental table 1).

1) Before the lecture. Teachers posted guidance of the course through an App called “Xuexi Tong” installed in Smartphone, which included the teaching schedule, introduction of course objectives, the key knowledge to be mastered, goal of ability nurturing (i.e. summarizing the course contents) and emotional attitude and values (i.e. understanding the position of undergoing course in whole medical system, developing good learning habits, and finding effective learning methods). These contents aimed to inform the students what the learning goals of the course are and how they could achieve the goals. In the “Xuexi Tong”, course-associated micro-lecture videos (total 80, 5–10 minute/video, 1–2 videos/session) based on the text book (Physiology, Ting-Huai Wang, People's Medical Publishing House, 9th Ed) were posted online to inform the students about the outline of the course and key contents, at least one day before the lecture. Students were required to watch them completely before the lecture. Some opening questions about the ongoing course lecture were also posted to guide students' learning by themselves before the lectures. In addition, some course-associated science stories and clinical cases

were posted to expand students' knowledge and enforce clinical association of the ongoing Physiology course with clinical applications.

2) In the lecture. After a sign-in through the App at 10 minutes before the lecture in classroom, some relevant topics/events were given to attract students into the course, such as mentioning respiratory symptoms of COVID-19 patients before introducing respiratory functions or broadcasting a heavy breathing sound to make students curious about the ongoing course contents or showing an image of the histology of the respiratory system to remind of students of the previously learned knowledge. An earlier posted micro-lecture video or other associated short teaching video was played to generate quizzes from simple factual contents to analytic consideration to inspire students' thinking. Alternatively, a multi-choice question (Supplemental table 2) was sent to the students as a pre-assessment via "Xuexi Tong". The answers of students to the questions could be calculated automatically, which generated a statistical graph of the answers and gave a direct reference for teacher to catch the major problems puzzling the students. This information allowed the teacher to adjust main lecture contents and explain why the right answer should be selected and how the wrong answers should be avoided in the subsequent main lectures.

In the main lecture, to enhance students' initiatives in learning, several interactive sessions were carried out, e.g. group discussion, student-led presentation of specific contents and clinical case analysis. A smart phone shake was used to select student to answer questions randomly in these processes. These activities were designed to enhance students' interest in learning and deepen their understanding and memory of course contents.

After the participatory learning, a post-assessment was performed with 3 ~ 5 multi-choice questions to evaluate how well the students master the knowledge and whether the aims of course are achieved. This assessment also gave teacher the opportunity to help students correct their misunderstandings of the course contents through summation of the course contents and online discussion or feedback at the beginning of next lecture. At last, a summary of the course contents was given by the teacher or the students under the supervision of the teacher to highlight the key contents based on blackboard writing with emphasis marks and associated figures in PPT.

3) After the lecture: A mind map (Supplemental Fig. 1) was posted online by the teacher to guide students to summarize the lecture contents by themselves. All students posted their course summary online for further discussion, which aimed to help students build a holistic view of the course. The students could ask questions individually about course and the mind map through internet by posting questions in the discussion section in "Xuexi Tong" or having a private conversation with teachers, which let them get the answers without limitation of the time and space.

Evaluation

To assess the effect of applying HBOPPPS model on teaching effectiveness, we compared the final scores between different teaching model groups. The final examination of Physiology course was worthy

of 100 points, consisting of 50 multi-choice and single answer questions (1 point/question) and 50 points of subjective questions, i.e., 6 short (5 points each) and 2 long (10 points each) essays. In addition, there was also an online score generated automatically by the system of “Xuexi Tong”, which was not counted into the final score but used to assess students’ initiatives of self-learning. This online score consisted of micro-lecture video watching (30 points), homework for each Chap. (40 points), test (10 points) and the attendance (20 points). Lastly, we did a survey through questionnaire (Supplemental Table 3) in Class2019 at the end of the semester of 2020 to analyze the effectiveness of HBOPPPS on students’ learning ability, which included finding, analyzing and solving a problem and teamwork. A total of 506 valid questionnaires were collected and they were all from the students of Class 2019.

Data analysis

All analysis was performed using SigmaStat program (SPSS 19, Chicago, IL). Comparisons of the final scores between different years were performed using one-way ANOVA followed by Bonferroni or Dunnett T3 test. Correlation analysis was performed between individuals’ final score and the online score. Comparisons between rates were carried out using chi-square test. Data are expressed as mean $\pm$ SEM. $P < 0.05$ was considered significant.

Results

Students' final examination scores

To evaluate the effectiveness of HBOPPPS, the scores of objective questions, subjective questions and the total scores of the final examination from Class 2017, 2018 and 2019 were compared. There was a significant increase in the total score of Class 2019 (83.9 ± 0.5) that was taught with HBOPPPS model compared to Class 2017 that was taught with traditional offline teaching method and Class 2018 that was taught by incomplete HBOPPPS (81.1 ± 0.6 in Class 2017, $P < 0.01$; 82.0 ± 0.5 in Class 2018, $P < 0.05$ by ANOVA and the following Dunnett T3 test, Fig. 2A). This is mainly reflected in the increased score of subjective questions. As shown in Fig. 2A, the average score of subjective questions was significantly higher in Class 2019 than that of Class 2017 (38.2 ± 0.4 in Class 2017 and 41.6 ± 0.3 in Class 2019, $P < 0.01$ by ANOVA and following Dunnett T3 test).

It is worth noting that Class 2018 also had higher subjective question scores than Class 2017 (41.4 ± 0.3 , $P < 0.01$ by ANOVA following Dunnett T3 test, Fig. 2A). However, the objective score of multi-choice and single answer questions earned by Class 2018 was significantly lower than that of the Class 2017 and Class 2019 groups (40.5 ± 0.2 in Class 2018; 42.9 ± 0.2 in Class 2017, $P < 0.01$; 42.3 ± 5.3 in Class 2019, $P < 0.01$ by ANOVA and following Bonferroni test, Fig. 2A).

We also analyze the distribution of students’ number in different score sections and found that the rate of excellence (scores between 90 and 100) of the Class 2019 (197, 38.0%; $P < 0.01$ by chi-square test) was clearly higher than that of Class 2017 (159, 29.9%) and Class 2018 (142, 27.0%). And the rates of poor or

failure (scores lower than 60) of the Class 2019 (15, 2.9%; $P < 0.05$ by chi-square test) was significantly lower than that of Class 2017 (36, 6.8%) and Class 2018 (26, 4.9%, Fig. 2B).

With the assistance of App “Xuexi Tong”, we could also give students an online score automatically as an evaluation of students’ learning initiatives that is usually important for learning efficiency. The average online score of the four parts were as the follows: micro-lecture video watching (26.9 ± 0.37 points), homework for each Chap. (38.1 ± 0.16 points), test (9.0 ± 0.08 points) and the attendance (19.8 ± 0.03 points), respectively. Correspondingly, we analyzed the online score and its correlation with the final score. We found that there was a weak but significantly positive correlation between the online score and the final score ($r = 0.14$, $P < 0.001$ by Pearson correlation, Fig. 3).

Students’ evaluation

Nowadays, with the expansion of quality education, the examination score is not the only criteria for assessing the quality of students. Learning ability is a very important assessment criterion in the quality education. Thus, a questionnaire was performed in Class 2019 after the completion of whole Physiology courses to evaluate this HBOPPPS method. As shown in Fig. 4A, a total of 86.2% students were satisfied with this HBOPPPS and about 1.6% of them were not satisfied because of several reasons which we would analyze later. There were also about 79.4% students who perceived that HBOPPPS improved their learning ability. There were only 4.3% of the students who thought that HBOPPPS didn’t help very much and 16.2% of the students who had no idea about this question (Fig. 4B).

Advantages and disadvantages

Any teaching model has its own advantages and disadvantages. Our survey revealed that students perceived the following advantages of HBOPPPS. The two dominant reasons were conducive to reproduce the learning content after class (73.5%) and effectively improved the learning efficiency (72.1%). In addition, 50% of the students thought that HBOPPPS was flexible to apply the learning content (54.2%) and could broaden their knowledge (50.2%) (Fig. 5).

By contrast, some disadvantages of this new teaching model were also perceived by students. That is, in online searching answers to discussion questions and expanding their knowledge, it was difficult to distinguish whether the resources that they found were suitable or not (63.0%), the preview task was heavy to accomplish (52.0%) and the teaching pace was too fast for some students to follow (40.3%) (Fig. 6).

Students’ choice

At the end of the questionnaire, we asked students about their teaching model preference. Among 506 responsive students from Class 2019, 61.7% of them showed a preference on the HBOPPPS (Fig. 7). A part of students (30.2%) still preferred to receive the traditional offline teaching which was used over the

whole process before college. In addition, a small portion of the students (8.1%) preferred the online only teaching model.

Discussion

The present study reveals that the HBOPPPS teaching model can significantly enhance the final score and the learning ability of students. This effectiveness is because HBOPPPS model takes full advantages of BOPPPS and the convenience of internet teaching as well as enhanced learning initiative of students.

Online teaching and BOPPPS

Electronic learning emerged in the middle of 1990s and it can be broadly defined as any type of educational media delivered through the internet [18]. The online course was not well established in China until 2020 when the COVID-19 pandemic occurred [19]. Classically, web-based learning, such as video lectures and Massive Open Online Course [3–5], enhances acquisition of expanding scope of the knowledge on the subject taught in classroom. Thus, it only serves as supplements for offline lecture. Since online resources of learning themselves are not helpful to resolve individual difficult problems and to stimulate students' enthusiasm for learning, it do not match the course objectives tightly and cannot flexibly link different sets of knowledge directly.

In the HBOPPPS, BOPPPS elements were fully incorporated into the teaching process. The six elements of BOPPPS [13] have their unique functions in enhancing learning efficiency. First, bridge-in has a good structure of class beginning with something interesting as the bridge between teachers and students. Second, students can learn the aims of the course and have a general understanding of the content by emphasizing them at the beginning of lectures. Third, the pre-assessment is a challenge for students and guides their attention to the main lecture. Fourth, BOPPPS emphasizes a participatory learning which puts stress a student-centered approach and can inspire the initiative of students. Fifth, the post-assessment would let the teacher know how well the students have mastered the content and what they need to be taught immediately. Finally, a summary is necessary that can give the students a mind mapping of the course content and in turn strength their memory. However, in the era of Internet plus, the HBOPPPS is necessary and effective in achieving a better teaching outcome than either the online or offline teachings.

In the present study, the HBOPPPS model, combining the benefits of online teaching and the advantages of BOPPPS model of offline teaching, largely resolves the limitations of classical online teaching model while compensating the space and time limitations of offline teaching, broadening students' knowledge, and enforcing teacher-student interactions, and therefore has better teaching effectiveness.

Hybrid teaching method

Pure online teaching simulating the BOPPPS offline teaching can partially resolve the limitation of classical web-based learning since it has clear goals and allows interactions between teacher and

students directly. However, a 5-year study showed that the full online course have higher fail rate than the face-to-face offline course[20]. Our initial trial applying a hybrid teaching model in Class 2018 by providing students with full lecture in BOPPPS model plus micro-video lecture online did not yield ideal results, particularly in their answering objective questions .During the spring semester of 2020, all of the schools in China were forced to apply full-time online courses due to COVID-19 pandemic. However, the students might not be well prepared for it and did not have good examination scores (our unpublished data). These facts led us to design the present HBOPPPS model that contains both the merits of online and offline teaching. The results reveal that this hybrid teaching model can activate students' interest, help them perform self-study and expand the depth of what they learned [21]. In addition, students really like the interactions with teachers given by the offline course and the possibility to perform small group work in an online environment. Correspondingly, they are mostly in favor of the hybrid course, a finding consistent with the reports from other groups [22, 23].

In our preparation of the teaching, 80 home-made micro-lecture videos were recorded and posted on "Xuexi Tong" that is the platform for students to participate in the online teaching and interactions as well as for calculation of students' activities automatically. Additionally, it is convenient for the feed-forward and feedback communications between teachers and students. Thus, "Xuexi Tong" becomes a powerful tool in establishing this HBOPPPS model.

Factors contributing to the effectiveness of HBOPPPS

The HBOPPPS group of Class 2019 had significantly better results than that of Class 2017 and 2018 for teaching effectively, as measured by the final exam scores. Besides, Class 2019 also had the higher rate of excellence and lower rate of failure, which indicates that the HBOPPPS has effectively improved students' learning efficiency and outcomes. This finding was consistent with other reports that revealed the higher effectiveness of the hybrid teaching than traditional methods [24, 25].

Analyzing the reason of students' improvement, we found that the final exam scores had a positive relationship with the online score coming from the App's calculation, which could reflect students' activity on learning Physiology. Both the BOPPPS offline and the online teachings are designed to enhance students' interest, activities and learning ability and thus make them to think and study independently and creatively. The advantages of HBOPPPS from the feedback of students include that it is convenient to reproduce the course content and effectively improves students' learning efficiency. In addition, timely-feedback interactions between the teacher and students are also attributable to the better outcomes of HBOPPPS model.

Notably, the home-made micro-lecture videos are very popular among students; combining with the online guideline, they become an effective venue for the students to master the key knowledge in the lecture. This finding is consistent with other studies that showed that there is a positive correlation between micro-lectures and the final scores [26, 27]. The weak correlation coefficient between them is likely because the less differentiated performance of online activities of the students, a feature different from that of international medical students [16].

Through the analyzing of questionnaire, we could see that most of the students satisfied or very satisfied with this teaching model since the HBOPPPS did improve their learning ability. In Class 2019, 61.7% of students expressed their preference for using this hybrid teaching method in future studies. This finding gives us the confidence in performing the HBOPPPS in teaching of Physiology in future.

Limitations and further improvements

Notably, most of the students thought it was difficult to distinguish whether or not the online resources that students found were suitable for discussion. This is a common problem for all of the people surfing the web in this era since everyone can express their own ideas on the internet, high or low quality, and they need to distinguish these messages carefully, which clearly increases the burden of their study. The second disadvantage or reason that 30% of the students didn't like this hybrid teaching is that they thought it was a heavy load to accomplish the preview task and course assignments. This is likely because Chinese students are used to traditional "filled-in" offline teaching which they just need to listen and then remember. By contrast, this HBOPPPS model requires them to learn by themselves first and that makes them feel a kind of pressure. However, a pressure doesn't mean bad since it can also be a driving force to promote college students' ability of self-learning, in general. In addition, the improvement of students' ability to answer multi-choice and single answer questions is not significant compared to the classical BOPPPS model. This seems because the HBOPPPS has not put stress on keywords and definitions of individual facts while stressing on the analytical ability of the students due to the time limitation. Lastly, the minor difference in the components of HBOPPPS among different teachers could also be a contributor, such as option for interpreting the micro-video lecture or using pre-assessment with the quiz following the bridge-in, and students-led summary or teacher-led summary in the lecture, etc.

To make BOPPPS more effective, we have also developed a TESOT teaching model for the education of international medical students. TESOT was created based on our identification of the learning obstacles and teaching style preferences[17], and then resolving these problems by using the components of active-learning classrooms [28], assisted by online guidance [16]. In the present study, we also tried to incorporate some components of TESOT into the BOPPPS model, such as including quizzes before and after the main lecture and partial students-led summary. However, the learning obstacles that revealed in the present and previous studies [17] were not considered, such as the course connections, instructions on using online resources, and limitations of self-studying time.

To further improve the efficiency of teaching Physiology, it is necessary to refine the structures and contents of HBOPPPS model while reducing students' burden of self-learning. This effort, for example, can include stressing on the interconnections between course/lectures by adjusting the contents of micro-video lectures and quizzes, making the online instructions clearer, and strengthening the digestion of course contents by students-led summary in the classroom and avoiding open end of the online discussion.

Conclusions

In the pandemic of COVID-19, online teaching is a necessary portion of teaching in this society. A hybrid teaching model combining the online and offline is the direction of future teaching. In this study, the hybrid teaching model based on BOPPPS is proved to be more effective than either classical offline teaching or pure online teaching in Physiology education. Thus, more in-depth study and assessment of this HBOPPPS are warranted and prospectively yield fruitful outcomes in medical education.

Abbreviations

BOPPPS

A teaching method composed of six elements including bridge-in, learning objectives and outcomes, pre-assessment, participatory learning, post-assessment and summary.

HBOPPPS

a hybrid teaching method incorporating online teaching into BOPPPS components

TESOT

a teaching modality enriched with components of student-centered approach and online interactions targeting the learning obstacles in global medical education

Declarations

Ethics approval and consent to participate: All studies in this work involving human subjects complied with the Declaration of Helsinki and all methods were performed in accordance with the relevant guidelines and regulations of National Natural Science Foundation of China. This study on optimizing teaching methods did not involve biological experiment or put the subject at unreasonable risk and thus ethics approval and consent to participate were deemed unnecessary according to “ethical review measures for life sciences and medical research involving human beings” (Order No. 11 of the National Health and Family Planning Commission of China, December 2016). Correspondingly, ethics approval and consent to participate for this study were waived by the ethnical committee of Harbin Medical University.

Consent for publication: Yes

Availability of data and materials: Available upon request

Competing interests: No conflicts of interest, financial or otherwise, are declared by the authors.

Funding: This work was supported by the Higher Education Talents Funds of Heilongjiang Province under Grant (No. 002000154); the Fund of "Double-First-Class" Construction of Harbin Medical University; Key Project of “14th Five-Year” Plan of Heilongjiang Province Education Science under Grant (No. GJB1421259) and Higher Education Teaching Reform Project of Heilongjiang Province Education Department under Grant (No. SJGY20180325).

The role of the funding body: The funding bodies supporting the execution of the designed study did not directly participate in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Authors' contributions: Xiao-Yu Liu, Chunmei Lv, Hui Zhu and Haixia Wen contributed to the study conception and design; Xiao-Yu Liu and Chunmei Lv wrote the first draft; Yu-Feng Wang contributed to the interpretation of data and revision of the paper.

Acknowledgements: Not applicable

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Figures

Figure 1

Constitution design of HBOPPPS

Figure 2

The difference and the distribution of students' final examination scores among three Classes. A. The comparison of average scores. B. The distribution of students' scores. ** $P<0.01$, compared to Class 2017. # $P<0.05$, ## $P<0.01$ compared to Class 2019.

Figure 3

Correlation between the final examination score and the online score.

Figure 4

Percentage of students' evaluation about HBOPPPS. A. Survey of students' satisfaction. B. Survey of the improvement of students' learning ability.

Figure 5

The advantages of HBOPPPS.

Figure 6

The disadvantages of HBOPPPS.

Figure 7

Students' choices about teaching method in the future.

Supplementary Files

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