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Hybrid BOPPPS model in radiology education: a case study of pediatric undergraduates

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Abstract

Background To explore the application effect of the hybrid BOPPPS (bridge-in, objective, pre-assessment, participatory learning, post-assessment, and summary) teaching model in radiology education for five-year pediatric undergraduates.

Methods A total of 418 students from Grade 2018 and 2019 majoring in Pediatrics of Chongqing Medical University were selected as the retrospective study objects. 213 undergraduates in Grade 2018 were included in the traditional lecture-based learning (LBL) group, and 205 undergraduates in Grade 2019 were included in the hybrid BOPPPS group. The primary endpoint was the comprehensive grades, which combined formative assessment scores (40%) and final exam scores (60%). The teaching effectiveness was evaluated by the assessment and questionnaires of the two groups of students, adjusting for multiple comparisons in the questionnaires with Bonferroni correction.

Results Compared to the LBL group, the hybrid BOPPPS group demonstrated statistically significant yet modest improvements in formative assessment (median difference: + 1.25 points), final exam (+ 2.0 points) and comprehensive grades (+ 1.6 points) (all $p < 0.05$). Students preferred the BOPPPS model more than the LBL model in terms of course enthusiasm, language proficiency, diagnostic reasoning and imaging interpretation ability, and teacher-student interaction (all $p < 0.00625$ after Bonferroni correction). However, the difference in self-learning ability improvement became non-significant post-correction ($p = 0.024 > 0.00625$). There was no significant difference in study pressure between the two groups ($p = 0.202$). And the BOPPPS group showed significantly higher levels of overall course satisfaction and effectiveness compared to the LBL group (both $p < 0.01$).

Conclusions The hybrid BOPPPS model is likely an effective radiology teaching method for five-year pediatric undergraduates, which is deserving of recommendation.

Keywords BOPPPS, Hybrid teaching model, Lecture-based learning, Radiology, Education theory

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Background

The BOPPPS teaching model originated in the Instructional Skill Workshop (ISW) from the University of British Columbia in 1978 [1], which divides into six distinct steps: bridge-in (B), objective (O), pre-assessment (P), participatory learning (P), post-assessment (P), and summary (S), i.e., BOPPPS. Based on the constructivism learning theory [2], the BOPPPS teaching model constructs a complete teaching process and theoretical framework for the achievement of teaching objectives, forms a closed loop teaching unit, and pays more attention to the effectiveness of teaching objectives and interaction with students, which is student-centered [3, 4]. Radiology, also called medical imaging, is a clinical discipline with strong combination of theory and practice. Traditional Chinese college and university teaching methods are mainly didactic, usually known as lecture-based learning (LBL), which can utilize a minimum number of teachers to convey a large amount of information to a great number of students [5, 6]. While traditional lectures can efficiently convey knowledge, they may not foster the deep learning needed for long-term retention, especially in fields like Radiology that require practical application of knowledge. Our university has adopted an organ-centered teaching reform in recent years. In the post-COVID-19 era, our radiology education has transitioned to an online and offline hybrid teaching model. This hybrid model integrates radiology teaching within clinical disciplines and utilizes online platforms, effectively supporting students' self-study and establishing learning nodes to facilitate the analysis of students' knowledge mastery. This poses greater demands on teachers to efficiently instruct within the constraints of classroom time.

Herein, this study was a feasibility study on the effectiveness of BOPPPS based on an online and offline hybrid teaching model in radiology education for five-year pediatric undergraduates.

Methods

Population/participants

The research is a comparative study. The participants comprised 418 undergraduate students in the five-year program at Pediatric College of Chongqing Medical University from September 1st, 2021 to December 30th, 2022. All undergraduates studied Radiology in their seventh semester. 213 undergraduates in Grade 2018 were included in the traditional LBL group, and 205 undergraduates in Grade 2019 were included in the hybrid BOPPPS group. There were 96 males and 117 females in the LBL group, with a mean age of 21.5 years (range: 21-23 years old), The BOPPPS group consisted of 99 males and 106 females, with an average age of 21.8 years (range: 21–23 years old). Students' admission scores range from 592–675, with mean points of 634.3 for the LBL group and 630.5 for the BOPPPS group. There were no significant differences in age, gender, and admission scores between these two groups (all $p > 0.05$), prompt for comparability of data.

Ethical approval

This study was performed in accordance with the Helsinki Declaration. This research comes from education reform project (the Education and Teaching Research Projects of Pediatric College of Chongqing Medical University NO. EY202020) and are exempt from Ethics Committee of the Children's Hospital of Chongqing Medical University. The informed consent was obtained from all participants in the BOPPPS group, distributed by the teaching assistant at the outset, prior to the commencement of the course. Conversely, participants in the control group (LBL group), who adhered to the conventional model, were not provided with information regarding the study.

Design

The educational material was Medical Imaging textbook (Xu K, Gong QY, Han P. 8th Ed. People's Medical Publishing House). The teaching administration allotted 16 lessons for the classroom teaching, 13 lessons for the online teaching, and 11 for practice teaching, with a total of 40 lessons and each one lasting for 40 min. There were two teaching assistants and one instructor in each lesson. Figure 1 is the flow chart of online-offline hybrid curriculum design.

Pre-class

Pre-class materials included coursewares (PowerPoint), videos, and preview materials (usually several questions about anatomy and pathology correlated with lessons, which are very important basic knowledge), as well as pre-learning assessment. The duration of each video is approximately 10 to 30 min, including typical radiological images of diseases and brief explanation of imaging features by teachers. Those videos were watched on the university's online education platform and will be documented as a learning node. Teaching assistants would upload pre-learning assessment materials for students online one month prior to the start of the curriculum, and provide preview questions one week before each class. Before this curriculum started, teaching assistants collected and graded assessment, then sent the result to the instructors to facilitate their preparation for the class.

In class

For the LBL group, the instructor explained the theoretical knowledge using PowerPoint, accompanied by the necessary pictures or videos. The students listened and

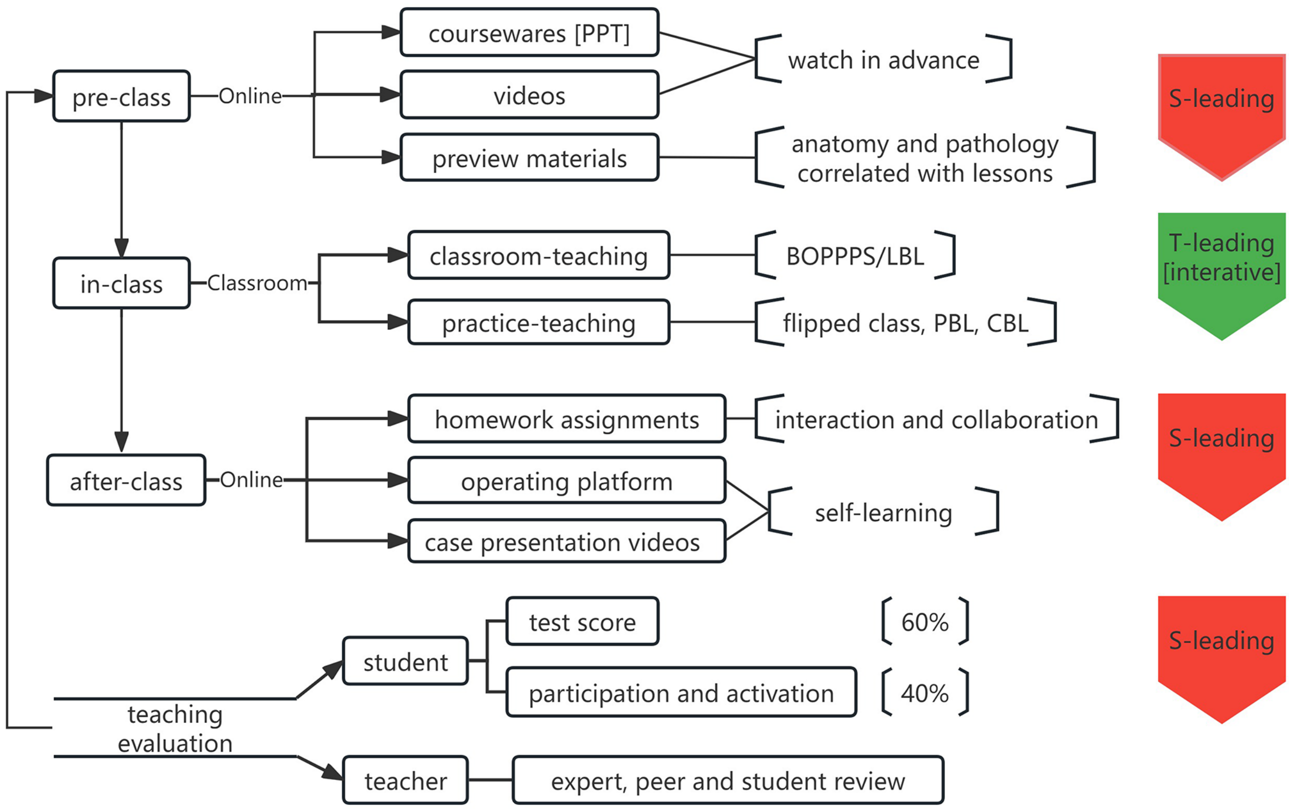

Fig. 1 Design of online-offline hybrid curriculum. (S-leading: student leading; T-leading: teacher leading)

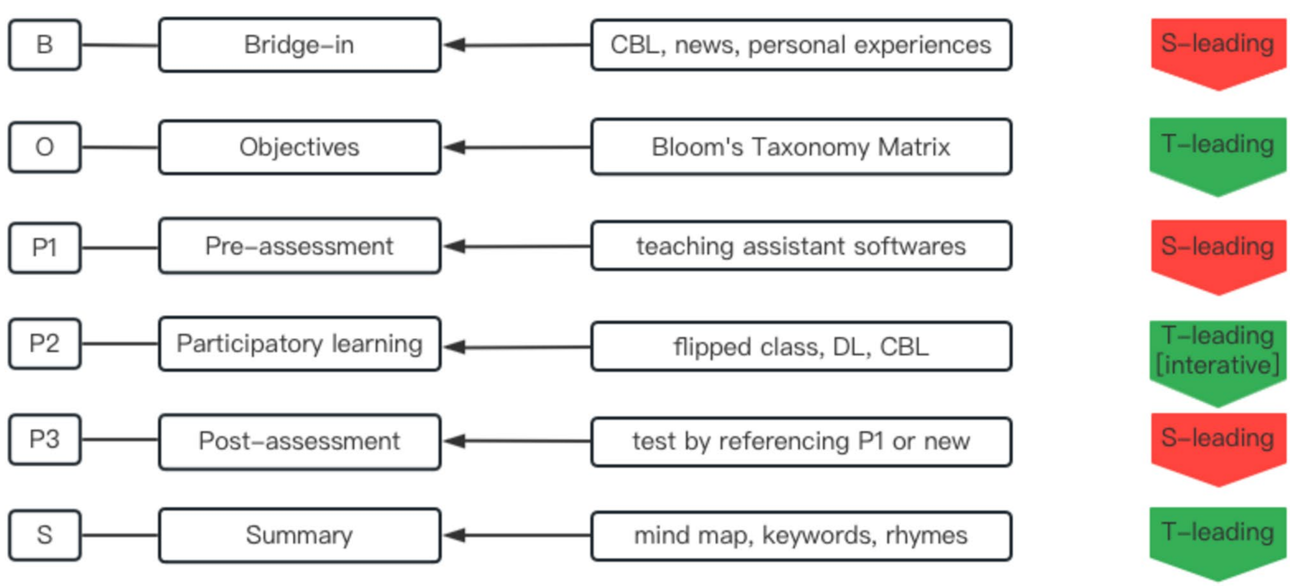

Fig. 2 Flow of diagram based on BOPPPS in classroom-teaching. (S-leading: student leading; T-leading: teacher leading; DL: discovery learning; CBL: case-based learning)

took notes. Finally, the instructor assigned homework to the students, which must be completed online. If the students had any questions, the instructor or teaching assistants answered them in the classroom or on the online platform after class.

For the BOPPPS group, the lessons were designed following the six steps of BOPPPS model based on the teaching content. Flow of diagram based on BOPPPS in classroom-teaching is shown on Fig. 2.

1. Bridge-in (B): Taking trauma in the central nervous system as an illustrative instance, the introductory component, known as “bridge-in” (B), could incorporate a concise video delineating the consistent occurrence of pediatric victims of traffic accidents undergoing CT examination. Such incidents, ordinary in our daily lives, become astonishing when portrayed. The key objective of designing this bridge-in section is to facilitate medical students in comprehending the primary subject matter of the course within a structured framework, as well as quickly awakening their profound zeal for learning.
2. Objective (O): According to the course syllabus of the Pediatric College of Chongqing Medical University, the objective (O) section clearly focuses on the typical imaging findings and differential diagnosis. Learning objectives include cognitive goals (professional theory), skill goals (practical ability), and ideological goals (humanistic literacy). They were designed and presented according to Bloom’s Taxonomy Matrix [7]. The learning objectives, with appropriate level of difficulty, are specific, measurable, and challenging, helping students overcome their fear of difficulty and engage in focused learning.
3. Pre-assessment (P): Create three single-choice questions by the teachers as pre-assessment (P), distribute them via the teaching assistant software during the class, and gather the responses to assess students’ prior knowledge and better tailor upcoming lectures.
4. Participatory learning (P): The fourth step, participatory learning (P), presents the greatest challenge for a teacher’s instructional skills and comprises the primary content of the teaching. It aligns with learning objectives and incorporates a variety of teaching methods like flipped class, discovery learning and case-based learning (CBL) to engage students in active participation during lessons. In addition to teacher-student interaction, peer-assisted learning [8] is strongly encouraged through student engagement in team work, fostering interaction and collaboration among peers.
5. Post-assessment (P): The test results should be able to offer feedback on the learning impact in the classroom, identify issues, rectify deviations, enhance teachers’ self-reflection on their teaching methods, and assist teachers in improving their teaching design further. As a result, a thorough and varied evaluation method is necessary for the post-assessment (P). In line with this, we have included 3 single-choice questions for all students to answer using educational software. They typically involve analyzing images related to the diseases in this course, in order to evaluate students’ ability in imaging diagnosis. These questions could be designed to assess the effectiveness of the lesson by referencing the content covered in the pre-assessment or introducing new material.
6. Summary (S): A concise summary (S) can assist in comprehending and internalizing the main points of the lesson, and can also act as a foundation for additional learning. Mind maps, keywords or rhymes are the methods we prefer to utilize.

In addition to traditional classroom instruction, there are practice sessions offered for radiological image interpretation, led by two experienced teaching assistants from our department. The primary instructional approaches utilized include flipped classroom [9], problem-based learning (PBL) [10], and CBL [11].

After class

Following each class, the homework assignments were posted online. The teacher was accessible through a discussion forum to offer guidance and clarification on any questions or doubts that the students may have had. The promotion of active peer-to-peer interaction and collaboration was also emphasized. Besides, students were encouraged to take advantage of the available teaching resources such as the case presentation video library (https://cooc.cqmu.edu.cn/Course/175.aspx) and an online simulation platform (http://qiao.chinacpss.com/childrenpacs), which were independently created by our teaching and research office, for their self-learning and revision.

Upon finishing the course, students are required to fill out an online questionnaire evaluating the effectiveness of the teacher’s teaching methods. The questionnaire distribution was managed by a teaching assistant who monitored the overall completion status (e.g., overall response rate) without access to individual respondent identities. This approach enabled the assistant to send general reminders to encourage questionnaire completion while maintaining participant anonymity, thereby ensuring a 100% response rate. The questionnaire mainly includes course enthusiasm, self-learning ability, language proficiency, diagnostic reasoning and image interpretation ability, teacher-student interaction, study pressure, teaching satisfaction, and overall teaching effectiveness (Additional file 1). This survey adopted a five-point Likert-type scale, and 1–5 points means completely disagreement-completely agreement.

Teaching evaluation

Teaching evaluation is a fundamental component of the teaching system that provides feedback on instruction, assists in the continual improvement of teaching practices, and ensures constructive alignment between learning objectives, teaching instructions, and assessments. This process not only fosters a cyclical improvement in teaching but also promotes life-long learning for the teacher. The evaluation process involved both assessing students and evaluating teachers. The student assessment was divided into two components. 40% of the assessment was allocated to formative evaluations, which were based on performance and scores obtained from image interpretation exercises during practice classes. The scoring for formative assessments encompasses several key components: performance scores from practical sessions (20% of the overall scores), online activity scores (10%), and mid-term examination scores (10%). Notably, the performance scores from the practical sessions represent the average scores obtained across 11 such classes. Detailed evaluation criteria and rating scales for these assessments are provided in Table 1. The remaining 60% was determined by summative evaluations based on the final exam scores. The primary endpoint of this study was the comprehensive grades, which combined formative assessment scores and final exam scores.

On the other hand, the teacher assessment primarily relied on the analysis of questionnaires and test papers completed by the students.

Statistical analysis

All statistical analyses were carried out using SPSS 22.0 (SPSS, Inc., Chicago, IL). Categorical data were analyzed by the chi-square test. Continuous data were first tested for normality with the Kolmogorov-Smirnov test, mean ± standard deviation (M ± SD) was described for the normally distributed data, and an unpaired t test was used for comparisons. Non-normally distributed data were represented by median (25%, 75% quantiles), and the Mann-Whitney U test was used for analysis [12]. Bonferroni correction was applied for multiple comparisons in the questionnaires with an adjusted significance threshold of $\alpha = 0.00625$ (0.05/8). Statistical significance was defined as $p < 0.05$, except in multiple comparisons where the adjusted α was applied.

Results

Comparison of final examination results between the BOPPPS and LBL groups

The BOPPPS group exhibited higher scores in formative assessment, final (theoretical) exam and comprehensive grades compared to the LBL group (all $p < 0.05$), as shown in Table 2.

Comparison of the questionnaire between two groups

A total of 418 questionnaires were distributed and 418 valid questionnaires were collected, with an effective recovery rate of 100%. The results of the two groups are shown in Table 3.

The results showed that the evaluation of teaching methods in the BOPPPS group was significantly better than that of the LBL group in terms of stimulating course

Table 1 Evaluation criteria and rating scales for the practical sessions

Evaluation Criteria	Description	Rating Scale	Comments
Participation	The student's engagement in class activities, including raising hands to speak, group discussions, etc.	5 = Very Active; 4 = Active; 3 = Average; 2 = Inactive; 1 = Never Participates	
Focus	The student's ability to concentrate during class time	5 = Highly Focused; 4 = Focused; 3 = Average; 2 = Unfocused; 1 = Never Focused	
Task Completion	The student's completion of class tasks and assignments, including image interpretation	5 = Always Completes on Time; 4 = Often Completes; 3 = Occasionally Completes; 2 = Rarely Completes; 1 = Never Completes	
Collaborative Skills	The student's cooperation in group activities	5 = Very Cooperative; 4 = Cooperative; 3 = Average; 2 = Uncooperative; 1 = Never Cooperative	
Cognitive Engagement	The student's ability to ask and solve problems in the classroom	5 = Highly Engaged; 4 = Engaged; 3 = Average; 2 = Disengaged; 1 = Never Engaged	
Rule Adherence	The student's compliance with classroom rules	5 = Always Follows; 4 = Often Follows; 3 = Occasionally Breaks; 2 = Often Breaks; 1 = Never Follows	
Emotional Attitude	The student's emotional expression in the classroom, such as positive or negative	5 = Very Positive; 4 = Positive; 3 = Average; 2 = Negative; 1 = Very Negative	
Learning Strategies	The student's use of learning strategies during the learning process, such as note-taking, asking questions, etc.	5 = Effectively Uses; 4 = Uses; 3 = Occasionally Uses; 2 = Seldom Uses; 1 = Never Uses	
Time Management	The student manages time effectively to complete tasks and stay on track.	5 = Excellent; 4 = Good; 3 = Satisfactory; 2 = Needs Improvement; 1 = Poor	
Critical Thinking	The student asks thoughtful questions and demonstrates the ability to analyze information.	5 = Excellent; 4 = Good; 3 = Satisfactory; 2 = Needs Improvement; 1 = Poor	
Total	These practical sessions constitute 50% of the formative evaluations.	**50 points (total = 100)**	

Table 2 Comparison of formative assessment scores, final (theoretical) exam scores, and comprehensive scores between the BOPPPS and LBL groups (points)

Group	BOPPPS ($n = 205$)	LBL ($n = 213$)	Z value	P value
Formative assessment scores	95.00 (92.50, 96.25)	93.75 (91.25, 96.25)	-2.943	0.003
Final exam scores	81.50 (77.00, 86.00)	79.50 (72.50, 85.50)	-2.133	0.033
Comprehensive scores	86.60 (82.95, 89.80)	85.00 (79.90, 88.85)	-2.854	0.004

Notes: The formative assessment scores, final exam scores and comprehensive scores of the two groups were non-normal distribution, and Mann-Whitney U test was used to analyze the difference between the two groups

Table 3 Comparison of the questionnaire between two groups

Question	BOPPPS ($n = 205$)	LBL ($n = 213$)	t value	P value
course enthusiasm	4.33 ± 0.62	4.00 ± 0.59	5.518	**<0.001**
self-learning ability	4.10 ± 0.55	3.97 ± 0.58	2.270	0.024
language proficiency	4.08 ± 0.56	3.89 ± 0.58	3.437	**0.001**
diagnostic reasoning and image interpretation ability	4.21 ± 0.74	3.68 ± 0.66	7.753	**<0.001**
teacher-student interaction	4.40 ± 0.65	3.76 ± 0.71	9.570	**<0.001**
study pressure	3.70 ± 0.56	3.63 ± 0.54	1.277	0.202
teaching satisfaction	4.39 ± 0.67	3.79 ± 0.75	8.551	**<0.001**
overall teaching effectiveness	4.23 ± 0.70	3.75 ± 0.69	7.047	**<0.001**

This survey adopted a five-point Likert-type scale (1, strongly disagree; 2, disagree; 3, neutral; 4, agree; 5, strongly agree). Values are means ± SD

enthusiasm, improving learning autonomy, exercising language expression proficiency, training diagnostic reasoning and improving imaging interpretation ability, and enhancing teacher-student interaction, and the difference was statistically significant (all $p < 0.05$). After Bonferroni correction for multiple comparisons (adjusted $\alpha = 0.00625$), all items of initial significant differences remained statistically significant (all $p < 0.00625$) except for self-learning ability ($p = 0.024 > 0.00625$). There was no significant difference in study pressure between the two groups ($p = 0.202$). Overall, the BOPPPS group showed significantly higher levels of satisfaction and effectiveness in the course compared to the LBL group (both $p < 0.01$).

Bonferroni-adjusted significance level: $\alpha = 0.05/8$ comparisons 0.00625. Significant values are in bold.

Discussions

Radiology is a critical medical field that connects clinical practice with basic science through imaging for disease diagnosis and treatment. Our five-year-program medical students, with limited clinical exposure, are at a crucial stage for developing diagnostic skills [13, 14]. Traditional LBL teaching often falls short in engaging students and fostering self-directed learning, impacting their practical skills. The BOPPPS model presents an innovative approach to educational reform [15, 16]. This study explored the effectiveness of incorporating the BOPPPS model into our hybrid online and offline teaching approach in pediatric Radiology education.

In our study, we implemented the hybrid BOPPPS model, which is based on an online and offline teaching approach, in radiology education for five-year pediatric undergraduates. Compared with the traditional LBL model, the results demonstrated that the hybrid BOPPPS model enhanced students' performance on exams, increased satisfaction with teaching, and improved overall effectiveness. These results are in alignment with prior research conducted across multiple medical fields, encompassing internal medicine, surgery, nursing, physiology, and pathology [4, 17–20].

For the radiology course, the exam grades and the skill to interpret images are important assessment indicators, which forms comprehensive grades. The findings of this study demonstrated that the hybrid BOPPPS group had significantly better grades compared to the LBL group without increasing study pressure, which was consistent with the results of previous studies in other medical disciplines [21]. These superior outcomes could be attributed to the BOPPPS model's comprehensive emphasis on participatory learning, enhancing students' focus, and fostering intrinsic motivation for learning [4, 21]. Systematic, coherent and operational BOPPPS six-step teaching model [22] can effectively guide and assist students in understanding the teaching focus and acquiring knowledge with clear goals, ultimately leading to improved comprehensive grades. This is achieved through teacher-student interaction, teaching satisfaction and overall teaching effectiveness, as indicated by our findings. Additionally, developing diagnostic reasoning skills is a gradual and ongoing process that is essential to Radiology. In the hybrid BOPPPS model, teachers can lead students in analyzing real clinical cases, understanding the imaging characteristics, and ultimately summarizing the relationship between the clinical and radiological manifestations of the disease. This will help deepen their comprehension of the disease, enhance their diagnostic reasoning and language expression, and improve their ability to interpret medical images. At the same time, we also offer an online operating platform for students to consolidate their professional skills. Although the 1–2% score difference between the BOPPPS and LBL groups seems small in our study, it represents meaningful progress in student outcomes. The BOPPPS model can not only improve academic performance but also significantly enhance diagnostic reasoning skills and engagement, which are vital for long-term learning and clinical practice, particularly in radiology for medical students.

Moreover, a strong passion for learning, fueled by internal motivation [23], and the ability to study independently, underpinned by autonomy [24], also play a crucial role in developing the lifelong learning capability [25] of pediatric undergraduates [26]. This will help students better solve complex practical problems and adapt to the rapidly evolving society and medical technology about Radiology. Our findings demonstrated that the hybrid BOPPPS model may significantly enhance student enthusiasm for Radiology, though improvement in self-learning ability exhibited only a marginal trend that did not withstand Bonferroni correction, potentially due to limited statistical power or modest effect sizes. While further validation through larger-scale studies is warranted, this model has been extensively demonstrated to play a significant role in other disciplines [3, 27, 28], underscoring its value in radiology education. Due to the enhancement of exam grades, practical skills, and self-learning capabilities, students are generally satisfied and highly rate the effectiveness of this teaching model.

Limitations

This study has some limitations. First, cross-academic year cohort comparisons may introduce temporal confounders such as curriculum reforms or shifting learner demographics. Second, the modest absolute improvements (+1.25-2.0 points) may reflect Hawthorne effect [29] from BOPPPS' structured interactivity, where novel pedagogical elements transiently inflate engagement metrics in initial implementation cycles. This underscores the need for multi-semester trials to isolate sustained learning gains from novelty-driven artifacts. Third, the single-semester intervention leaves long-term educational outcomes unverified. Finally, although our in-house assessment tool employs a classic five-point Likert scale and is informed by established formative assessment literature, its validity and reliability may be context-specific and require further validation in different settings.

Conclusions

In conclusion, our findings demonstrate that the hybrid BOPPPS teaching model is effective for educating five-year pediatric undergraduates in Radiology. This teaching model has a significant influence on their exam grades and the ability to analyze images, as it enhances teacher-student interaction, student's diagnostic reasoning and language expression, teaching satisfaction, and overall teaching effectiveness. Additionally, it also increases students' interest in Radiology. Therefore, it is a recommended teaching method.

Abbreviations

BOPPPS	Bridge-in learning objective pretest participatory learning posttest and summary
CBL	Case-based learning
LBL	Lecture-based learning
PBL	Problem-based learning

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-025-07279-4.

Supplementary Material 1

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Author contributions

CWQ, HL and FX contributed to the study conception and design.CWQ, HL and CJH contributed to analysis and interpretation of the data.CWQ drafted the manuscript.CJH and FX revised the final version of the manuscript.All authours have read and apporved the final manuscript.

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Data availability

The data used and analyzed during the study are available from the corresponding author on reasonable request.

Declarations

Ethical considerations

This study was performed in accordance with the Helsinki Declaration. This research comes from education reform project (the Education and Teaching Research Projects of Pediatric College of Chongqing Medical University NO. EY202020) and are exempt from Ethics Committee of the Children's Hospital of Chongqing Medical University. The informed consent was obtained from all participants in the BOPPPS group, distributed by the teaching assistant at the outset, prior to the commencement of the course. Conversely, participants in the control group (LBL group), who adhered to the conventional model, were not provided with information regarding the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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