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# Evaluating an Integrated PBL–MDT–Flipped Classroom Approach for Teaching Acute Coronary Syndrome to Undergraduate Medical Students

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## Abstract

Medical education is undergoing rapid transformation, with increasing emphasis on learner-centered and integrative instructional strategies. Among these, problem-based learning (PBL), multidisciplinary treatment (MDT), and flipped classroom models have attracted growing interest in clinical teaching. Despite their individual advantages, limited evidence is available regarding the combined effectiveness of PBL, MDT, and flipped classroom approaches in cardiovascular disease education. Given the complementary strengths of these methods, this study aimed to investigate the application and educational impact of an integrated PBL–MDT–flipped classroom model in case-based instruction on acute coronary syndrome (ACS). A total of 100 undergraduate students majoring in clinical medicine at Guangzhou Medical University (aged 20–21 years) were enrolled in this study. Using a random number table, participants were allocated into two equal groups: an experimental group (n = 50), which received instruction using a combined PBL, MDT, and flipped classroom approach, and a control group (n = 50), which followed conventional teaching methods. Following completion of clinical training, both groups were assessed using theoretical examinations and practical skill evaluations. In addition, a structured questionnaire was administered to assess students' perceptions of teaching effectiveness.

Students in the experimental group achieved significantly higher scores in both theoretical examinations and clinical skill assessments compared with those in the control group ($P < 0.05$). Questionnaire findings further demonstrated that the experimental group showed superior performance in learning motivation, mastery of theoretical knowledge, clinical reasoning, literature-search competence, self-directed learning, practical skills, and overall classroom satisfaction. All differences between groups were statistically significant ($P < 0.05$). The results indicate that integrating PBL, MDT, and flipped classroom strategies may enhance both theoretical understanding and clinical competency among undergraduate medical students studying ACS. Nevertheless, interpretation of these findings should consider the study's limitations, including the relatively small sample size, short follow-up duration, and reliance on self-reported questionnaire data.

**Keywords:** Flipped classroom, PBL, MDT, Acute coronary syndrome

## Introduction

Problem-based learning (PBL) has become one of the most widely adopted instructional strategies in contemporary medical education. Originating in the 1950s, PBL emphasizes learning driven by clinical problems rather than passive knowledge transmission [1]. In this approach, instructors facilitate student-centered learning through structured stages of problem identification, analysis, discussion, and solution development. By actively involving learners in these processes, PBL promotes engagement, stimulates curiosity, and encourages initiative. Moreover, participation in collaborative problem-solving enhances communication skills, critical thinking, and independent learning habits, while strengthening interaction between teachers and students as well as among peers [2, 3].

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The flipped classroom model represents another influential innovation in educational practice. First proposed in 2006 by chemistry educators Jonathan Bergmann and Aaron Sams, this model reverses the traditional sequence of instruction by shifting initial knowledge acquisition to the pre-class phase and reserving classroom time for discussion, application, and problem-solving [4]. Since its introduction, the flipped classroom has been widely adopted across disciplines and has gained particular relevance in medical education. This method redefines the roles of both teachers and learners, fostering a more interactive and student-driven learning environment. By encouraging learners to review instructional materials such as videos and presentations independently before class, the flipped classroom allows in-class time to be used for deeper analysis, clarification of difficult concepts, and clinical discussion. As a result, this approach supports personalized learning, enhances self-regulated study skills, and moves beyond the limitations of traditional lecture-based instruction [5–8].

Multidisciplinary treatment (MDT) was initially developed at the MD Anderson Cancer Center in the United States as a collaborative model for cancer diagnosis and management. MDT emphasizes coordinated decision-making among professionals from multiple specialties, shifting clinical care from a disease-centered paradigm to a patient-centered approach characterized by precision, comprehensiveness, and individualization [9]. Owing to its effectiveness in addressing complex clinical conditions, MDT has gained widespread recognition not only in clinical practice but also in medical education. From an educational perspective, MDT-based teaching exposes students to diverse disciplinary viewpoints, enabling them to understand diseases more holistically and to appreciate the complexity of individualized patient management. Incorporating MDT into case-based learning helps overcome the limitations of single-discipline teaching, which often provides fragmented or superficial knowledge [10, 11].

Recent evidence suggests that combining innovative teaching strategies may produce synergistic educational benefits. For example, Zhou *et al*. reported that integrating PBL with the flipped classroom in cardiology education significantly improved students' clinical reasoning abilities and knowledge retention compared with traditional teaching approaches [12]. Similarly, Feng *et al*. demonstrated that blending MDT with competency-based education in respiratory rehabilitation nursing enhanced student satisfaction and performance in clinical simulation settings [9]. These findings indicate that multimodal instructional designs may better address the demands of modern medical training than isolated teaching methods.

Conventional teaching approaches for acute coronary syndrome (ACS) typically emphasize theoretical instruction and individual clinical skills, with limited integration of active learning or team-based perspectives. However, both PBL and the flipped classroom are designed to increase learner engagement and promote higher-order thinking skills [12, 13], while the MDT model reflects real-world clinical practice in which interdisciplinary collaboration is essential [14]. ACS, characterized by its clinical urgency and complexity, was therefore selected as the focus of this study. Effective management of ACS requires not only solid theoretical knowledge but also the ability to synthesize information from multiple disciplines, including cardiology, pharmacology, critical care, and medical imaging. Relying on a single teaching strategy may be insufficient to address these multifaceted learning requirements.

Each instructional approach also has inherent limitations when used independently. PBL may lack the systematic knowledge delivery offered by flipped classroom preparation, while the flipped classroom alone may not adequately simulate interdisciplinary clinical decision-making. Likewise, MDT discussions without a foundation in self-directed learning and structured problem-solving may fail to cultivate independent clinical reasoning. Integrating these methods offers the potential to offset individual weaknesses and create a more comprehensive and effective learning environment.

In recent years, Guangzhou Medical University has actively promoted innovative teaching reforms, including organ system–centered curricula, PBL, and flipped classroom models, yielding notable improvements in students' innovation and practical abilities. Despite these advances, challenges remain during clinical clerkships, where many students struggle to integrate knowledge from disciplines such as pathophysiology, diagnostics, radiology, and internal medicine. Common issues include weak logical reasoning, limited clinical judgment, and excessive reliance on instructor-led teaching. Addressing these challenges requires the integration of multiple educational strategies that capitalize on their respective strengths.

Given its typical clinical presentation and educational suitability, a representative ACS case was selected for this study. The present research therefore aimed to examine the application and effectiveness of a combined PBL, MDT, and flipped classroom teaching model in the clinical clerkship education of undergraduate medical students focusing on acute coronary syndrome.

## Materials and Methods

*Participants*

A total of 100 undergraduate students enrolled in the clinical medicine program at Guangzhou Medical University, aged between 20 and 21 years, were recruited for this study. Participants were randomly allocated into two equal groups (n = 50 per group) using a random number table. The experimental group received instruction using an integrated teaching model combining problem-based learning (PBL), multidisciplinary treatment (MDT), and the flipped classroom approach, whereas the control group was taught using conventional instructional methods.

To minimize instructional bias, the same faculty member delivered the theoretical lectures to both groups. Clinical clerkship activities were overseen by a team of three senior instructors, each with more than 10 years of clinical teaching experience. All participants provided written informed consent prior to enrollment. Ethical approval for the study was obtained from the Institutional Review Board and Ethics Committee of the Third Affiliated Hospital of Guangzhou Medical University.

*Study design*

All participating students had previously completed core foundational courses, including Human Anatomy, Physiology, Pathophysiology, Pathology, Pharmacology, Biochemistry, Molecular Biology, Cell Biology, and Diagnostics, ensuring a comparable baseline of medical knowledge. Teaching activities were conducted in accordance with the Internal Medicine Teaching Syllabus of Guangzhou Medical University.

The instructional program commenced with systematic theoretical teaching on diseases of the cardiovascular system, enabling students to establish a solid conceptual framework for understanding disease mechanisms, diagnosis, and clinical management prior to entering the clinical clerkship phase.

Except for the teaching methodology, all other instructional variables—including course content, teaching personnel, and total contact hours—were identical for both groups. The study was implemented during a two-week clinical internship period. Case-based instruction on acute coronary syndrome (ACS) was delivered in two sessions, each with a duration of 120 minutes.

*Control group*

Students assigned to the control group were taught using traditional lecture-based methods. Instruction focused on core aspects of ACS, including its pathophysiology, clinical presentation, diagnostic strategies, therapeutic interventions, and long-term management. Teaching was delivered primarily through instructor-led lectures supported by PowerPoint slides and printed handouts.

Learning in this group emphasized systematic transmission of theoretical knowledge, with limited opportunities for interactive discussion. Case-based elements were minimal and typically confined to brief in-class question-and-answer segments. No structured pre-class learning tasks or flipped classroom components were incorporated, reflecting the standard instructional approach used in the ACS curriculum at our institution prior to this study.

*Experimental group*

Students in the experimental group were instructed using a combined PBL, MDT, and flipped classroom teaching model. Based on the course syllabus and key learning objectives for ACS, instructors identified essential concepts and challenging topics and developed a structured PBL lesson plan. Pre-class learning resources, including recorded lecture videos and supplementary reading materials, were provided to students in advance. Students were required to review these materials independently and to search relevant databases, such as PubMed and the university library system, to collect additional information and compile study notes.

Participants were organized into small groups consisting of five to six students, with one student appointed as the group leader. Each student assumed the role of a clinician from a different specialty—such as cardiology, critical care medicine, respiratory medicine, ultrasound imaging, or pharmacy—thereby forming a simulated multidisciplinary treatment (MDT) team. Within this framework, groups conducted MDT-style discussions addressing key clinical questions related to ACS from their assigned disciplinary perspectives.

During the clinical clerkship, groups analyzed real patient cases under the supervision of a faculty instructor. Students integrated patient history, physical examination findings, and auxiliary diagnostic test results to explore diagnostic reasoning, differential diagnosis, and treatment planning. Group leaders presented the team's conclusions, while other members supplemented the discussion with additional insights. Emphasis was placed on clarifying the logical framework underpinning diagnostic and therapeutic decision-making. Following each presentation, instructors provided feedback, identified areas for improvement, and guided students in defining subsequent learning objectives to further encourage self-directed learning.

For selected representative cases, additional in-class discussion sessions lasting approximately 40 minutes were incorporated. Specific clinical questions were assigned in advance, with each group responsible for investigating one topic through literature review, information retrieval, and collaborative analysis. Students prepared written or oral reports prior to the clerkship. For example, in a case involving an elderly male patient presenting with acute chest pain and electrocardiographic ST–T segment abnormalities, guiding questions included diagnostic criteria, key considerations for differential diagnosis, required auxiliary investigations, and optimal treatment strategies. Through pre-class preparation and in-class discussion, students were able to apply theoretical knowledge more effectively when engaging with patients during the clerkship.

The PBL strategy employed in this study followed a hybrid format adapted from the classical McMaster model. Core components included small-group learning, use of authentic clinical cases, structured facilitation by instructors, and a two-stage process consisting of initial case discussion, independent self-directed study, and a subsequent session focused on problem resolution.

*Evaluation of teaching effectiveness*

To measure learning outcomes, a closed-book written examination was developed in alignment with the instructional content and administered to students in both groups to assess their theoretical knowledge. The examination comprised multiple-choice questions (MCQs) and was divided evenly into two components: foundational theoretical knowledge (100 points) and clinical case–based analysis (100 points). Item construction followed Bloom's Taxonomy of cognitive domains, with questions distributed across six levels: remembering (20%), understanding (30%), applying (25%), analyzing (15%), evaluating (7%), and creating (3%). Items assessing remembering and understanding were grouped under the "basic theoretical knowledge" section, whereas questions addressing higher-order cognitive processes were categorized as "clinical case analysis" [15, 16].

The reliability of the MCQ examination was evaluated using Cronbach's alpha, which yielded a coefficient of 0.82, indicating good internal consistency. For the practical skills assessment, inter-rater reliability was determined using Cohen's kappa statistic, resulting in a value of 0.89, which reflects a high degree of agreement between examiners. Prior to the main study, the assessment instruments underwent pilot testing with a small group of students from the same academic cohort who were not involved in the intervention, ensuring clarity and feasibility of the evaluation tools.

Teaching effectiveness was further assessed using a structured questionnaire specifically developed by the authors for this study. To minimize response bias, the survey was administered anonymously to both the experimental and control groups. The questionnaire evaluated seven dimensions of learning outcomes: learning motivation, effectiveness of theoretical knowledge acquisition, clinical reasoning ability, literature retrieval skills, capacity for self-directed learning, practical competence, and overall classroom satisfaction. Each item was presented in a dichotomous (Yes/No) format, and the proportion of affirmative ("Yes") responses was calculated for each domain.

Statistical analyses were subsequently performed to compare both examination performance and questionnaire responses between the two groups. The internal consistency of the teaching effectiveness questionnaire was assessed using Cronbach's alpha, which produced a value of 0.78, indicating acceptable reliability.

A schematic representation of the overall study design is provided in **Figure 1**.

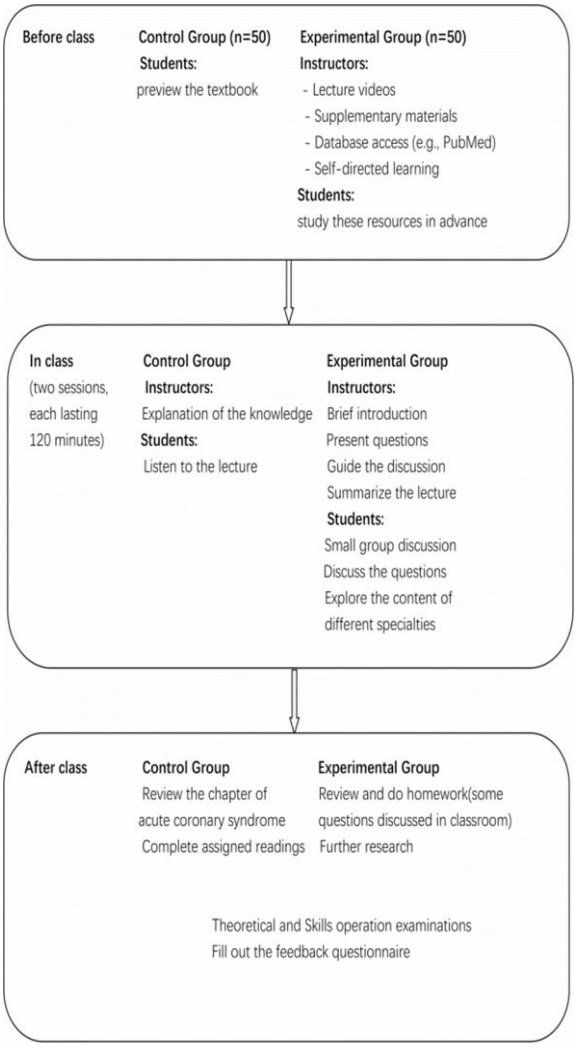


**Figure 1.** Schematic illustration of the overall study framework.

*Statistical analysis*

All statistical analyses were conducted using SPSS software (version 23.0; Chicago, IL, USA). Categorical variables are presented as frequencies and percentages [n (%)], and intergroup comparisons were performed using the chi-square ($\chi^2$) test. Continuous variables are reported as mean ± standard deviation ($\bar{x} \pm s$), and differences between groups were analyzed using the independent-samples t test. Statistical significance was defined as a two-tailed P value less than 0.05 ($P < 0.05$).

## Results and Discussion

*Comparison of baseline characteristics between groups*

As summarized in **Table 1**, no significant differences were observed between the experimental and control groups with respect to age or sex distribution, indicating comparability of baseline demographic characteristics between the two cohorts.

**Table 1.** Comparison of general information between the two groups

| Group | Number | Gender (male/female) | Age (years old, $\bar{x}\pm s$) |
|---|---|---|---|
| Control group | 50 | 31/19 | 20.96 ± 0.83 |
| Experimental group | 50 | 26/24 | 21.02 ± 0.84 |
| T/$\chi$2 value | | 1.020 | 0.358 |
| *P* value | | 0.313 | 0.721 |

There were no statistically significant differences in age or sex between the control and experimental groups ($P > 0.05$)

*Comparison of examination performance between groups*

The experimental group outperformed the control group in both theoretical and practical assessments. Specifically, their average theoretical score was 86.10 ± 4.35, higher than the control group's 83.42 ± 5.06, while their practical skills score averaged 78.46 ± 4.97, compared to 75.30 ± 4.29 in the control group. These differences reached statistical significance ($P < 0.05$), as summarized in **Table 2**.

**Table 2.** Comparison of exam scores between the two groups

| Group | Number | Theoretical Exam Scores($\bar{x}\pm s$) | Skills Exam Scores($\bar{x}\pm s$) |
|---|---|---|---|
| Control group | 50 | 83.42 ± 5.06 | 75.30 ± 4.29 |
| Experimental group | 50 | 86.10 ± 4.35 | 78.46 ± 4.97 |
| T value | | 2.837 | 3.403 |
| *P* value | | 0.006 | 0.001 |

The experimental group outperformed the control group in both theoretical and skills exams, with statistically significant differences ($P < 0.05$)

*Comparison of learning outcomes between groups*

In this study, 100 questionnaires were administered to evaluate seven areas: learning motivation, theoretical knowledge acquisition, clinical reasoning, literature search proficiency, self-directed learning, practical skill performance, and overall satisfaction with classroom experience. Respondents indicated their satisfaction with

each item by selecting "yes" or "no," and the percentage of affirmative responses was calculated. All questionnaires were returned fully completed and considered valid. Analysis revealed that the experimental group consistently reported higher satisfaction rates than the control group across all seven domains. These differences were statistically significant ($P < 0.05$), as detailed in **Table 3**.

**Table 3.** Comparison of teaching effectiveness survey results between the two groups

| Group | Number | Learning Motivation | Learning Effectiveness | Reasoning Ability | Search Skills | Learning Ability | Practical Skills | Classroom Satisfaction |
|---|---|---|---|---|---|---|---|---|
| Control group | 50 | 39 | 35 | 36 | 33 | 32 | 41 | 37 |
| Experimental Group | 50 | 46 | 45 | 48 | 45 | 43 | 49 | 47 |
| $\chi 2$ | | 5.138 | 6.250 | 10.714 | 8.392 | 6.453 | 7.111 | 7.440 |
| *p* value | | 0.023 | 0.012 | 0.002 | 0.004 | 0.011 | 0.008 | 0.006 |

The findings from **Table 3** indicate that the experimental group surpassed the control group across all evaluated dimensions, encompassing learning motivation, theoretical knowledge acquisition, clinical reasoning skills, literature retrieval proficiency, self-directed learning capacity, practical competencies, and overall classroom satisfaction. These intergroup differences achieved statistical significance ($P < 0.05$).

Conventional pedagogical approaches in medical education, especially for acute coronary syndrome (ACS), tend to emphasize the transmission of theoretical content and the development of isolated clinical skills. Predominantly lecture-oriented, these methods establish a solid knowledge base but often fall short in promoting active student involvement or replicating the collaborative, cross-disciplinary dynamics of actual clinical settings. Consequently, learners may remain underdeveloped in essential abilities such as critical thinking, problem-solving, and interprofessional teamwork required for handling intricate disorders like ACS, which demand integration of insights from various medical fields.

To overcome these shortcomings, contemporary educational techniques—including Problem-Based Learning (PBL), flipped classroom designs, and Multidisciplinary Team (MDT) frameworks—have attracted growing interest [17–19].

Acute coronary syndrome represents a frequent and life-threatening condition necessitating multidisciplinary expertise for accurate diagnosis, differentiation, and management [20]. This study examined the synergistic application of PBL, flipped classroom, and MDT methodologies in teaching ACS to undergraduate medical students. The integrated strategy was intended to rectify deficiencies in traditional instruction. Outcomes revealed marked enhancements in students' academic performance, clinical reasoning capabilities, and satisfaction levels, underscoring the merits of this blended approach in medical training.

PBL promoted active participation by prompting students to collaboratively dissect and resolve realistic case scenarios, thereby cultivating vital critical thinking and problem-solving competencies for complex cases like ACS. The flipped classroom, in turn, enabled independent pre-class preparation through review of lectures and scholarly materials, freeing in-class sessions for advanced cognitive tasks, such as applying theory to practical clinical problems.

Incorporating MDT sessions introduced a crucial interprofessional element, mirroring authentic healthcare environments. Students engaged with viewpoints from specialties including cardiology, pulmonology, intensive care, pharmacology, and radiology. This not only deepened comprehension of ACS but also strengthened teamwork and communication proficiencies indispensable for quality patient care. Of the three elements, MDT appears to have been pivotal in advancing clinical reasoning and problem-solving, with PBL and flipped classroom serving as supportive mechanisms to boost engagement and active learning.

Study results affirm that the experimental cohort achieved superior examination performance and higher satisfaction compared to controls, validating the versatile contributions of combining MDT, flipped classroom, and PBL in ACS clinical education.

First, this integration bolsters self-directed learning. The flipped classroom compels pre-session autonomous study via multimedia resources and readings, effectively

nurturing independent learning and self-regulation skills while shifting from passive absorption to proactive knowledge construction [21]. Experimental group students exhibited notable initiative in gathering data and collaborating on case presentations. Their robust preparation facilitated deeper grasp of clinical content and confident application during interactive discussions.

Second, it fosters critical thinking development. Through analytical debates, hypothesis generation, and peer/teacher exchanges, experimental students demonstrated heightened enthusiasm for inquiry and collaborative solution-seeking relative to controls. Greater teacher-student interactivity permitted tailored feedback and adaptive instruction, contrasting with conventional methods. This blended model mandates active involvement, optimizing knowledge retention and skill mastery via dynamic exchanges, with instructors adjusting in real time to learner needs.

Third, it markedly improves clinical reasoning and decision-making. These competencies extend beyond mere information delivery, requiring immersive practice. The combined PBL, flipped classroom, and MDT framework effectively supports this by encouraging advance preparation, independent problem identification, solution exploration, and instructor dialogue—yielding superior knowledge integration and reasoning advancement.

Although the PBL-MDT-flipped classroom combination yielded clear short-term gains, questions persist regarding long-term viability and sustained student satisfaction. Potential influences like novelty bias, workload demands, and ongoing adaptation warrant attention to preserve engagement. Longitudinal research is needed to assess enduring impacts and refine strategies for prolonged efficacy.

The rationale for merging PBL, MDT, and flipped classroom stemmed from their complementary advantages: PBL drives critical analysis and resolution skills; flipped classroom enhances autonomy and participation; MDT emulates interdisciplinary clinical reality. This synergy mitigates limitations of standalone use, aligning with evidence supporting hybrid active learning in medicine [1, 6]. Favorable results—elevated scores and satisfaction in the experimental arm—corroborate prior work on active and collaborative pedagogies [9, 12].

This investigation presents a novel pedagogical model integrating PBL, flipped classroom, and MDT discussions to tackle persistent challenges in ACS instruction. Traditional ACS teaching prioritizes theory and solitary skills, often neglecting active engagement and cross-disciplinary teamwork essential for real-world complexity. By fusing these interactive, team-oriented techniques, the model fills existing voids and offers a transferable template for other multifaceted medical subjects, paving the way for progressive, interdisciplinary advancements in medical education.

It is recognized that experimental group superiority might partially arise from novelty, heightened interactivity, or elevated faculty/student effort rather than the method alone. Despite uniform instructors, content, and duration across groups, the experimental format inherently featured distinct interaction patterns. This confounding factor is noted as a limitation, with suggestions for future investigations to isolate novelty and attention biases.

Although statistical significance was attained, such metrics should not exclusively define educational merit. Additional factors—including implementation practicality across institutions, long-term feasibility, resource implications for educators and learners, and broader curricular influence—deserve comprehensive evaluation.

*Limitations*

Although this study demonstrates the advantages of integrating Problem-Based Learning (PBL), Multidisciplinary Team (MDT) discussions, and flipped classroom techniques for teaching acute coronary syndrome (ACS), several limitations warrant cautious interpretation of the results. These include a modest sample size, a brief evaluation timeframe, and dependence on self-reported measures.

The research involved only 100 undergraduate medical students from one institution, restricting the broader applicability of the results to other medical programs that may vary in resources, student profiles, or curriculum design.

The intervention's effects were assessed over a short duration of two weeks, leaving unexamined longer-term outcomes such as sustained knowledge retention, actual clinical competence in practice, or influences on professional trajectories. Subsequent investigations should incorporate longitudinal follow-ups to evaluate enduring advantages.

Additionally, enhancements observed in the experimental group could partially stem from novelty bias or the greater demands placed on both faculty and

learners, rather than exclusively from the integrated pedagogy itself.

A further constraint arises from the simultaneous application of MDT, PBL, and flipped classroom elements, preventing isolation of each component's specific contribution—particularly MDT, which may have been the primary driver. Future work should examine MDT in isolation to better delineate its independent effects.

The absence of pre-intervention baseline assessments hinders confirmation that post-study improvements were solely attributable to the combined approach, as preexisting differences in preparedness between groups cannot be ruled out.

Participants were drawn exclusively from one Chinese medical school, potentially limiting representation of diverse global student populations with varying cultural backgrounds and learning preferences. Broader studies involving multiple regions and educational contexts would strengthen external validity.

While a single instructor delivered the theoretical components to both groups, the use of multiple facilitators during clinical rotations may have introduced inconsistencies in instructional quality and student engagement. Standardizing faculty training and implementation could address this variability.

Finally, the control group received no compensatory access to the innovative methods post-study, raising potential ethical issues related to educational equity. This is recognized as a study weakness, and it is recommended that future trials provide the enhanced intervention to all participants, either concurrently or sequentially, to promote fairness.

## Conclusion

This study indicates that combining PBL, MDT, and flipped classroom strategies can positively influence undergraduate medical students' theoretical understanding and clinical abilities in acute coronary syndrome (ACS). The noted gains in examination performance and learner satisfaction are encouraging; however, confirmation requires larger-scale, multi-center trials featuring extended follow-up periods and more comprehensive assessment methods to establish reliability and wider applicability.

Upcoming research should also address implementation barriers across varied educational environments, as well as the prolonged impacts on academic achievement and real-world clinical practice.

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