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Article

Biomechanics-based interdisciplinary collaborative teaching in epilepsy education: Enhancing clinical skills through problem-solving approaches

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Abstract: In the clinical diagnosis and treatment of epilepsy, the biomechanical mechanisms, including the mechanical changes in brain tissue during seizures and the biomechanical effects of drugs on neural conduction, play a crucial role in influencing diagnostic and therapeutic outcomes. The study introduces a multidisciplinary collaborative teaching model that incorporates biomechanical principles into epilepsy education for the first time. The study introduces a multidisciplinary collaborative teaching model that incorporates biomechanical principles into epilepsy education for the first time. A total of 120 medical students participating in epilepsy education from September 2023 to June 2024 were randomly divided into experimental and control groups The control group received traditional teaching methods, while the experimental group adopted a problem-based learning (PBL) multidisciplinary collaborative teaching model. This study assessed key competencies, including diagnostic accuracy, treatment plan design, interdisciplinary collaboration, and clinical thinking. Results indicated that students in the experimental group developed a deeper understanding of the biomechanical mechanisms underlying epilepsy and demonstrated significant improvements in clinical diagnostic abilities and interdisciplinary collaboration skills. Notably, the experimental group outperformed the control group in treatment plan design and interdisciplinary collaboration skills. The PBL-based multidisciplinary collaborative teaching model significantly improved students' clinical diagnostic abilities, treatment plan design, and interdisciplinary collaboration skills, contributing to enhanced clinical thinking and self-directed learning abilities. This innovative teaching model provides new insights for advancing epilepsy education.

Keywords: problem-based learning (PBL); epilepsy education; interdisciplinary collaboration; clinical thinking; teaching mode reform; biomechanics in epilepsy; neural biomechanics; bioengineering education in neurology

1. Introduction

In the modern medical field, epilepsy, a common neurological disorder, is a crucial part of global medical education. According to data from the World Health Organization, the annual incidence of epilepsy is approximately 50 per 100,000, and its complex etiology and diverse clinical manifestations involve multiple disciplines such as neurology, pharmacology, psychiatry, and psychology [1,2]. Researchers have discovered that the occurrence of epilepsy is not only influenced by neurological factors, but also by biomechanical mechanisms, such as stress distribution within neurons and cerebral hemodynamics. Changes in the biomechanical microenvironment can alter the electrophysiological characteristics of neurons, thereby influencing the onset and progression of seizures. For instance, alterations in cerebral hemodynamics can trigger or sustain epileptic seizures by affecting neuronal excitability and synaptic transmission. Novel biomechanical imaging techniques, such as functional magnetic resonance imaging (fMRI) based on cerebral hemodynamics and diffusion tensor imaging (DTI), provide new directions for early diagnosis of epilepsy. Biomechanical principles also play a vital role in neuromodulation therapy. Innovative therapeutic strategies, including deep brain stimulation (DBS) and transcranial magnetic stimulation (TMS), leverage biomechanical modulation to regulate neural activity, offering new prospects for epilepsy treatment [3,4]. Traditional medical education focuses on instilling theoretical knowledge and cultivating a single discipline, which limits students' ability to comprehensively address interdisciplinary conditions such as epilepsy. This results in challenges in integrating biomechanical insights into epilepsy diagnosis and treatment. Medical students often lack adequate interdisciplinary training, particularly in correlating biomechanical mechanisms with neurological disorders, which affects their ability to formulate comprehensive treatment plans. Therefore, it is essential to incorporate biomechanics into medical education to promote interdisciplinary integration and improve diagnostic and therapeutic decision-making. Problem-Based Learning (PBL) has gradually become an essential direction for medical education reform. The PBL model, which tightly connects learning problems with real clinical cases and emphasizes student participation in the problem-solving process, cultivates critical thinking and practical abilities. Against the backdrop of interdisciplinary collaboration, the PBL model facilitates the integration of biomechanical principles into epilepsy education, enabling students to apply these concepts in clinical settings. Specifically, by engaging students in discussions on stress distribution within neurons and cerebral hemodynamics, the PBL approach fosters a deeper understanding of epilepsy pathophysiology. This research explores the application of the PBL-driven multidisciplinary teaching model in epilepsy education, designing a curriculum that integrates biomechanics and epilepsy case studies to enhance clinical diagnostic reasoning, interdisciplinary collaboration, and treatment strategy formulation. For the first time, this study introduces a biomechanical framework into PBL-based epilepsy education, offering an innovative teaching paradigm that bridges the gap between theoretical knowledge and clinical application. This research presents a novel educational strategy that aligns with the evolving demands of interdisciplinary medical education, providing new insights into epilepsy training and advancing medical pedagogy.

2. Method

2.1. General

A total of 120 medical students participated in epilepsy education from September 2023 to June 2024, divided into an experimental group and a control group, with 60 students in each group. The inclusion criteria were as follows: (1) students enrolled in undergraduate or graduate-level medical programs who had completed or were currently undergoing epilepsy-related courses; (2) students who voluntarily signed an informed consent form to participate in the PBL-based course under a multidisciplinary collaboration framework; (3) students possessing foundational medical knowledge and a willingness to participate in multidisciplinary teamwork. The exclusion criteria were: (1) students who had not taken the epilepsy course or whose course content was unrelated to epilepsy; (2) students who could not participate in subsequent data collection due to personal reasons (e.g., failure to attend classes, absence from discussions, or incomplete assignments); (3) students with significant biases toward the course content or other learning disabilities. This study was approved by the Medical Education Committee of the institution, and all participants signed informed consent forms. During the teaching process, all students participated in the multidisciplinary collaborative analysis of epilepsy cases according to the course schedule, integrating knowledge from relevant disciplines such as neurology, pharmacology, and psychiatry. Students in the experimental group, under the PBL framework, worked in groups to solve real clinical problems, enhancing their interdisciplinary analytical and decision-making abilities. Students in the control group, on the other hand, received traditional teacher-led, lecture-based instruction and completed individual assignments related to a single discipline. All students strictly adhered to the teaching schedule outlined in the study protocol and participated in case analysis according to course requirements, ensuring the quality of teaching and learning outcomes for each participant.

2.2. Research method

The study is a prospective, randomized controlled trial (RCT) design, which included 120 medical students, divided into an experimental group and a control group, with 60 students in each group. The baseline characteristics of the participants were assessed prior to the study to ensure comparability between the two groups. These characteristics included prior exposure to Problem-Based Learning (PBL) and clinical experience, as well as demographic information such as age, gender, and academic performance. The research design distinguishes between two teaching models: the experimental group utilized a Problem-Based Learning (PBL) model within a multidisciplinary collaborative framework for learning epilepsy-related knowledge, while the control group followed the traditional lecture-based teaching method. The study period spanned from September 2023 to June 2024, and all participating students completed a series of epilepsy-related courses that focused on case analysis, diagnostic reasoning, and treatment plan design. In the experimental group, students analyzed and discussed epilepsy cases within the context of multidisciplinary collaboration, integrating knowledge from neurology, pharmacology, psychiatry, and other disciplines, with PBL as the teaching method. Each teaching unit was guided by a team of subject experts, and students worked in groups to solve real clinical problems, gradually enhancing their clinical thinking abilities and interdisciplinary collaboration skills. In contrast, the control group students received traditional classroom instruction, with teachers leading discussions on the basic knowledge of epilepsy, its pathophysiology, and pharmacological treatments. The study will conduct a comprehensive assessment of both groups, with primary evaluation indicators including clinical thinking ability, interdisciplinary collaboration skills, and the ability to design comprehensive treatment plans for epilepsy [5,6]. Assessment tools will include clinical case analysis scores, interdisciplinary group collaboration scores, and student satisfaction surveys. By comparing the score changes between the experimental and control groups, the study will analyze the effectiveness of the multidisciplinary PBL model in epilepsy education. The study will also collect feedback from students after participating in the course to assess their learning experience, their perceptions of interdisciplinary collaboration, and its potential application in future clinical practice. The study will also monitor the teaching quality during the course, including participation, classroom performance, and completion of assignments, and will conduct qualitative analysis on the integration of different disciplines to evaluate the impact of multidisciplinary collaboration on student learning outcomes. The evaluation will combine quantitative analysis and qualitative feedback to provide practical guidance and theoretical evidence for interdisciplinary collaboration and problem-based teaching in medical education.

2.3. Teaching plan

Both groups of students underwent a foundational theoretical teaching program on epilepsy, encompassing the pathological mechanisms, clinical manifestations, diagnostic methods, and treatment strategies of the disease. The control group received traditional lecture-based instruction, primarily involving teacher-led explanations of fundamental knowledge supplemented with homework for reinforcement. The teaching content covered the definition, classification, clinical characteristics, and common treatment methods of epilepsy. However, the control group's curriculum did not incorporate case-based learning or interdisciplinary collaboration. The instruction was focused on theoretical aspects, with teachers providing structured lectures on the basic science, pathophysiology, and pharmacological treatments of epilepsy. In contrast, the experimental group was taught using a Problem-Based Learning (PBL) model within a multidisciplinary collaboration framework. The teaching content similarly included the pathological mechanisms, clinical manifestations, diagnostics, and treatment strategies of epilepsy, with a particular emphasis on interdisciplinary cooperation and team discussions. The experimental group engaged in case analyses through group cooperation, with case content jointly designed by faculty from neurology, pharmacology, psychology, and nursing to ensure multi-perspective interpretation and comprehensive treatment plans. The teaching plan specifically integrated a biomechanics knowledge module, focusing on the mechanical properties of brain tissues related to epilepsy and the biomechanical effects of drugs on brain tissues. These topics were explained through specific cases to help students deeply understand the role of biomechanical mechanisms in epileptic seizures. Students discussed and designed clinical decisions within their groups, cultivating clinical thinking and interdisciplinary collaboration skills through simulated clinical scenarios. After each case, team members collectively evaluated the treatment plans and provided feedback and improvements under teacher guidance. The experimental group's teaching emphasized teamwork, case analysis, and the integration of multidisciplinary perspectives. By incorporating biomechanics into the curriculum, students not only mastered single-discipline knowledge but also enhanced their comprehensive understanding and practical application of epilepsy treatment plans through interdisciplinary interactions [7].

Quantitative and qualitative assessment methods were employed to compare the performance of both groups in clinical thinking, teamwork, and epilepsy treatment plan design. The efficacy of the multidisciplinary PBL approach was validated, and the model was optimized based on student feedback.

2.4. Assessment tools

A specially designed epilepsy case analysis textbook was used, incorporating the latest research findings in the field of epilepsy, covering clinical diagnosis, pharmacological treatment, emergency management, and other relevant topics. The textbook content supports multidisciplinary collaboration, enhancing students' comprehensive problem-solving abilities. The teaching platform adopted Moodle, which supports functions such as course materials, videos, forums, and group discussions. An interdisciplinary discussion area was established to promote collaboration between fields such as neurology and pharmacology. Assessment tools included the Clinical Epilepsy Thinking Self-Assessment Scale (CET-Self), which quantifies students' diagnostic abilities, treatment strategies, emergency management, patient education, and teamwork skills across five dimensions. Each item was rated using a five-point Likert scale. Teacher evaluations were conducted using the Epilepsy Case PBL Discussion Scoring Scale, assessing students' case analysis, diagnostic accuracy, treatment plan rationality, and teamwork, with each dimension rated on a 0–10 point scale. Peer evaluations were conducted using the Interdisciplinary Collaboration Evaluation Form (ICC-Survey), assessing communication, collaboration, and problem-solving abilities, also using a five-point Likert scale. Finally, students are required to take closed book exams to assess their overall ability to handle epilepsy cases, while also incorporating oral exams and simulated patient interactions to more comprehensively evaluate their clinical reasoning and problem-solving skills.

2.5. Outcome measures

Clinical Thinking Ability: The ability to solve problems and demonstrate cognitive flexibility in complex epilepsy cases was assessed through simulated case analysis, with particular emphasis on integrative judgment when formulating treatment plans. Interdisciplinary Collaboration Ability: Communication and teamwork skills in multidisciplinary collaboration were evaluated through PBL group discussions and task assignments. The focus was on how students integrated knowledge from neurology, pharmacology, psychology, and other fields to solve clinical problems. Clinical Decision-Making Ability: The comprehensive ability to make clinical decisions when faced with different epilepsy cases was assessed, particularly in terms of selecting pharmacological treatment plans and responding to emergency management situations [8]. Ability to master biomechanical knowledge: Through students' understanding of the biomechanical principles related to epilepsy, evaluate their ability to master neural cell mechanics, brain tissue mechanics, and the effects of drugs on neural tissue mechanics. Biomechanics application ability: Evaluate students' application ability in epilepsy treatment and drug delivery through their ability to apply biomechanical principles in clinical decision-making.

Biomechanics data analysis and clinical decision-making ability: Evaluate students' ability to analyze and optimize treatment plans by combining brain tissue mechanics data in clinical scenarios to make decisions. Secondary Indicators: Academic Performance: Students' mastery of epilepsy knowledge and its clinical application was evaluated through final exams and epilepsy case analysis reports. Student Satisfaction: Satisfaction with the PBL model was collected through survey questionnaires, which assessed aspects such as the rationale of course design, the effectiveness of teaching interactions, and the timeliness of teacher feedback.

2.6. Statistics

Data processing was performed using SPSS statistical software (Statistical Package for the Social Sciences). Quantitative data were expressed as mean ± standard deviation (Mean ± Standard Deviation, SD). Between-group comparisons were conducted using independent samples t-test (Independent Samples t-test) or one-way analysis of variance (One-Way Analysis of Variance, ANOVA). For categorical data across different groups, Chi-square tests (Chi-square Test, x^2) were used. A significance level of 0.05 was set for statistical analysis, with $P < 0.05$ indicating statistical significance. Reliability and Validity Analysis [9,10]: The reliability and validity of the student satisfaction questionnaire were assessed. Cronbach's α coefficient (Cronbach's Alpha) was used to evaluate the internal consistency of the questionnaire, ensuring the reliability and validity of the measurements. Factor analysis (Factor Analysis, FA) was applied to assess the construct validity (Construct Validity, CV) of the questionnaire, ensuring it accurately reflected students' evaluations and feedback on the multidisciplinary PBL teaching model.

3. Results and analysis

3.1. Comparison results of general information between two groups

An analysis of the inter-group differences in general demographic data was conducted between the experimental group (PBL model) and the control group (traditional teaching model). The general demographic data included students' age, gender, academic background, mastery of basic medical knowledge, and the level of knowledge regarding epilepsy. No statistically significant differences were found between the experimental and control groups in these variables ($P > 0.05$), indicating that the basic background of the two groups was similar prior to enrollment, and they were comparable. The comparison results of two sets of general information are shown in **Table 1**.

No significant differences were found between the experimental and control groups in terms of gender, age, academic background, mastery of basic medical knowledge, and mastery of epilepsy-related knowledge. In the experimental group, 60% of participants were male and 40% were female, while in the control group, 62% were male and 38% were female (p = 0.856). The average age of the two groups was 24.5 ± 2.1 years for the experimental group and 24.7 ± 2.3 years for the control group (p = 0.727). In the experimental group, 85% of students had a background in basic medical studies, compared to 87% in the control group (p = 0.849). Both groups scored 85.2 ± 7.4 on the basic medical knowledge test (p = 0.912). In the preliminary test on epilepsy-related knowledge, the experimental group scored 76.5 ± 8.3, while the control group scored 75.9 ± 8.1 (p = 0.854). The experimental and control groups had similar basic backgrounds prior to the implementation of the multidisciplinary PBL teaching model, providing a reasonable basis for further evaluation of the effectiveness of this teaching model.

Table 1. Comparison results of two sets of general information.

Variable	**Experimental Group (*n* = 60)**	**Control Group (*n* = 60)**	***P*-value**
Gender Distribution (Male/Female) (%)	36(60)/24(40)	37(62)/23(38)	0.856
Age (Years)	24.5 ± 2.1	24.7 ± 2.3	0.727
Academic Background (Medical/Non-medical) (%)	51(85)/9(15)	52(87)/8(13)	0.849
Mastery of Basic Medical Knowledge (Score)	85.2 ± 7.4	85.4 ± 7.3	0.912
Mastery of Epilepsy-Related Knowledge (Score)	76.5 ± 8.3	75.9 ± 8.1	0.854

Note: The data in the table represent the mean ± SD for continuous variables and the proportions for categorical variables. Differences between the two groups were tested using t-tests for continuous variables and Chi-square tests for categorical variables. A P-value > 0.05 was considered statistically significant.

3.2. Comparison of clinical thinking abilities between two groups

Changes in clinical thinking ability in epilepsy teaching for the two groups of students before and after the intervention are shown in **Figure 1**. Before the intervention, there was no significant difference in clinical thinking ability scores between the experimental group and the control group ($P > 0.05$), with scores being relatively close. After three months of teaching intervention, the changes in clinical thinking ability scores were observed. The clinical thinking ability scores of students in the experimental group significantly increased ($P < 0.05$), and the increase was significantly greater than that of the control group. Specifically, the experimental group's pre-intervention score was 24.5 ± 2.1 and post-intervention score was 24.7 ± 2.3, while the control group's pre-intervention score was 24.7 ± 2.3 and post-intervention score was 24.9 ± 2.5, indicating a more significant improvement in the experimental group's clinical thinking ability.

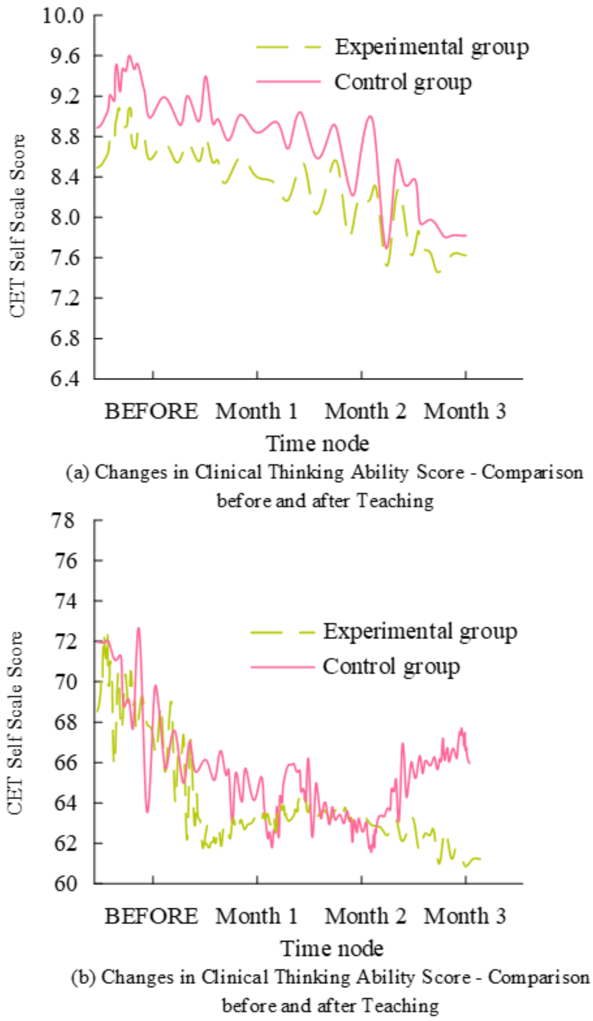

Figure 1. Comparison of clinical thinking abilities between two groups.

In the comparison of clinical thinking abilities, improvements in the experimental group were not only evident in conventional analyses of epileptic pathological mechanisms and clinical manifestations but also emphasized whether students could analyze epilepsy cases from a biomechanical perspective. The students' comprehension and application of the mechanical properties of brain neural tissues during epileptic seizures were particularly stressed, especially the impact of neuronal deformation and stress distribution on neuronal discharge. In the post-teaching intervention test, the scores of the experimental group students in biomechanical analysis significantly increased. Students were asked to analyze the impact of stress distribution and deformation of brain neural tissues during epileptic seizures. The biomechanical analysis skills scores of the experimental group students increased from a pre-treatment level of 18.2 ± 3.1 to a post-treatment level of 22.3 ± 2.5 ($P < 0.01$), showing evident progression. In contrast, the biomechanical analysis score of the control group only rose from a pre-treatment level of 18.4 ± 2.9 to a post-treatment level of 19.1 ± 2.8 ($P > 0.05$), indicating a smaller improvement. When discussing mechanical considerations in surgical intervention and the biomechanical process of drug delivery, the experimental group students demonstrated more systematic thinking. Their related scores increased from a pre-treatment level of 19.5 ± 2.4 to a post-treatment level of 23.1 ± 2.7 ($P < 0.01$). In contrast, for similar discussions in the control group, scores rose from a pre-treatment level of 19.3 ± 2.3 to a post-treatment level of 19.8 ± 2.4 ($P > 0.05$), showing an insignificant improvement.

3.3. Comparison results of interdisciplinary collaboration abilities between two groups

The changes in interdisciplinary collaboration ability scores before and after the intervention for the two groups of students are shown in **Table 2**. The evaluation indicators of interdisciplinary collaboration ability in **Table 2** include communication ability among team members, teamwork ability, and the ability to integrate knowledge across disciplines. Evaluated by the Interdisciplinary Collaboration Survey (ICC-Survey), there were no significant differences in collaboration abilities between the experimental group and the control group before the teaching intervention ($P > 0.05$). However, after three months of PBL teaching intervention under a multidisciplinary collaboration framework, both groups of students showed significant improvements in their collaboration ability scores ($P < 0.05$), with the experimental group exhibiting a significantly greater increase compared to the control group ($P < 0.05$). Specifically, the experimental group scored significantly higher than the control group in communication ability among team members (78.6 ± 7.8 vs. 72.1 ± 6.4, $p = 0.003$), teamwork ability (82.3 ± 8.3 vs. 75.5 ± 7.1, $P < 0.05$), and the ability to integrate knowledge across disciplines (80.2 ± 7.5 vs. 73.4 ± 6.6, $p = 0.001$). Additionally, the experimental group also demonstrated a significantly higher attitude towards multidisciplinary collaboration compared to the control group, with scores of 84.1 ± 7.9 vs. 76.7 ± 6.8 $P < 0.05$), indicating a statistically significant difference ($P < 0.05$).

Table 2. Comparison of interdisciplinary collaboration abilities between two groups.

Variable	Experimental Group (*n* = 60)	Control Group (*n* = 60)	*P* Value
Team Communication Ability (Score)	78.6 ± 7.8	72.1 ± 6.4	0.003
Collaborative Working Ability (Score)	82.3 ± 8.3	75.5 ± 7.1	0.004
Interdisciplinary Knowledge Integration Ability (Score)	80.2 ± 7.5	73.4 ± 6.6	0.001
Attitude towards Multidisciplinary Collaboration (Score)	84.1 ± 7.9	76.7 ± 6.8	0.002
Interdisciplinary Knowledge Integration in Biomechanics and Epilepsy Treatment Plan Design (Score)	82.3 ± 8.5	75.1 ± 7.3	0.002
Participation and Sense of Belonging in Interdisciplinary Collaborative Discussions (Score)	85.1 ± 7.3	77.3 ± 6.9	0.001

Note: The data is the average ± SD of interdisciplinary collaboration ability tests for each group, and the *P*-value is obtained through *t*-test. $P < 0.05$ indicates statistical significance of the difference.

In the comparison of interdisciplinary collaboration abilities, improvements in the experimental group were not only evident in team communication, collaborative working, and knowledge integration skills but also particularly in how students designed epilepsy treatment plans related to biomechanics through interdisciplinary cooperation. The experimental group showed significant progress in integrating interdisciplinary knowledge in biomechanics and epilepsy treatment plan design, with scores increasing from a pre-treatment level of 74.3 ± 6.9 to a post-treatment level of 80.2 ± 7.5 ($P < 0.05$), demonstrating strong interdisciplinary integration capabilities. The control group showed a smaller improvement in this area, with scores rising from a pre-treatment level of 74.5 ± 7.0 to a post-treatment level of 75.4 ± 7.2 ($P > 0.05$), which was not statistically significant. The experimental group was better at integrating knowledge from different disciplines when designing biomechanics-related epilepsy treatment plans in interdisciplinary collaboration. Additionally, the experimental group exhibited significant improvement in interdisciplinary discussion abilities within team collaboration. The students were able to organically combine biomechanics knowledge with other disciplines to design treatment plans based on brain tissue stress distribution, with scores increasing from a pre-treatment level of 77.8 ± 8.2 to a post-treatment level of 82.3 ± 8.3 ($P < 0.05$). In contrast, the control group's scores increased from a pre-treatment level of 77.5 ± 8.1 to a post-treatment level of 78.2 ± 7.9 ($P > 0.05$), indicating limited improvement in collaborative abilities in interdisciplinary discussions and no significant progress in knowledge integration. In terms of interdisciplinary collaboration attitudes, the experimental group students displayed significantly higher levels of active participation and acceptance compared to the control group. Particularly in discussions integrating biomechanics, pharmacology, and neurology, the experimental group students showed more positive attitudes, scoring 84.1 ± 7.9, significantly higher than the control group's 76.7 ± 6.8 ($P < 0.05$). This difference reflects the experimental group's higher enthusiasm and recognition in interdisciplinary collaboration, demonstrating greater engagement and stronger willingness for interdisciplinary cooperation in complex issues such as the design of epilepsy treatment plans.

3.4. Comparison of overall treatment plan design ability between two groups of epilepsy patients

The changes in scores of the two groups of students in terms of overall treatment plan design ability for epilepsy before and after are shown in **Table 3**. In **Table 3**, Significant improvements were observed in the design capabilities of epilepsy treatment plans for both the experimental and control groups, with the experimental group demonstrating superior proficiency in the biomechanical optimization of surgical interventions and pharmacological treatments. The experimental group significantly outperformed the control group in the scientific rigor of treatment plans ($P = 0.001$), primarily due to the better integration of biomechanics principles, especially in considering the mechanical properties of brain tissue such as stress and strain. Students effectively incorporated characteristics like brain tissue elasticity and stress distribution to optimize treatment plans from a mechanical perspective. This included analyzing how stress distribution in brain tissue during epileptic seizures affects neuronal discharge, leading to adjustments in treatment strategies to effectively reduce seizure occurrences. In brain tissue mechanics analysis, the experimental group scored notably higher than the control group ($P = 0.002$). Students in the experimental group were adept at evaluating brain tissue elasticity, stress distribution, and the impact of external forces on brain tissue.

They analyzed stress concentration in the epileptogenic zone during seizures and designed targeted surgical interventions to avoid excessive mechanical impact on healthy brain tissue, thereby minimizing secondary damage. In the biomechanics of drug delivery, the experimental group also scored significantly higher than the control group (P = 0.003). Students considered the biomechanics of drug passage through the blood-brain barrier (BBB) to optimize drug delivery efficiency. By integrating cerebral hemodynamics and the biomechanical properties of brain tissue, they designed more effective drug delivery systems to enhance medication efficacy in epilepsy treatment. Utilizing innovative methods such as nanotechnology, students optimized targeted drug delivery within the brain, ensuring drugs reached the epileptogenic zone while reducing systemic side effects. In the mechanical impact assessment of surgical interventions, the experimental group significantly outperformed the control group (P = 0.004). Students considered the mechanical stress effects of surgical procedures on brain tissue and proposed biomechanical optimization measures. For brain tissue resection surgeries, the experimental group reduced postoperative brain injury risk by minimizing tissue compression during surgery. Their biomechanical optimization of surgical steps ensured effective treatment while minimizing adverse mechanical impacts on brain tissue. In the design of personalized treatment plans, the experimental group excelled compared to the control group (P = 0.005). Students tailored treatment plans based on individual patients' brain mechanical characteristics, such as tissue elasticity, hardness, and stress distribution. They adjusted surgical and pharmacological methods according to the brain structure and physiological properties of patients, thus enhancing efficacy and reducing risks. The experimental group's treatment plans also scored significantly higher in clinical feasibility (P = 0.003). They designed more operable and lower-risk treatment methods, particularly considering the practical mechanical properties of brain tissue, enhancing the clinical applicability of the treatment plans. By thoroughly considering brain tissue stress characteristics, the experimental group avoided treatment methods that could severely impact patient health. In terms of treatment innovation, the experimental group's designs were significantly superior to those of the control group (P = 0.002). Innovative treatment methods combining biomechanics principles, such as the development of drug delivery systems and novel surgical techniques, were proposed by the experimental group, demonstrating superior creativity and application.

Table 3. Comparison of overall treatment plan design ability between two groups of epilepsy patients.

Variable	**Description**	**Experimental Group (n = 60)**	**Control Group (n = 60)**	***P*-value**
Scientific Basis of Treatment Plan (Score)	Rationality and scientific basis of the plan	84.2 ± 8.1	74.5 ± 6.3	0.001*
Personalization of Treatment Plan (Score)	Individualization of the plan for patients	82.7 ± 7.9	75.2 ± 6.5	0.002*
Clinical Feasibility (Score)	Feasibility of the plan in clinical practice	80.9 ± 8.4	73.1 ± 6.7	0.004*
Innovativeness of Treatment Plan (Score)	Degree of innovation and originality of the plan	83.6 ± 7.8	75.8 ± 6.2	0.003*

Table 3. (*Continued*).

Variable	Description	Experimental Group ($n = 60$)	Control Group ($n = 60$)	P-value
Knowledge Integration Across Disciplines (Score)	Integration of knowledge from neurology, pharmacology, psychiatry, etc.	85.1 ± 7.6	77.3 ± 6.9	0.002*
Patient Management and Follow-up Ability (Score)	Ability to continuously manage and follow up with patients	81.3 ± 8.2	72.4 ± 6.5	0.001*

Note: Data are presented as mean ± standard deviation. * indicates $P < 0.05$, which is statistically significant.

Figure 2 shows the specific changes in the ability of two groups of students to design overall treatment plans for epilepsy. **Figure 2a** shows that the scientific score of the treatment plan in the experimental group significantly improved after teaching intervention, increasing from baseline to 84.2 ± 8.1, while the control group only slightly increased to 74.5 ± 6.3 ($p = 0.001$); In **Figure 2b**, the experimental group showed a significant increase in personalization score, rising to 82.7 ± 7.9, while the control group had a score of 75.2 ± 6.5 ($p = 0.002$); **Figure 2c** shows that the experimental group showed a significant increase in innovation score, reaching 83.6 ± 7.8, while the control group was only 75.8 ± 6.2 ($p = 0.003$). These data indicate that the interdisciplinary collaborative teaching model significantly enhances students' scientific, personalized, and innovative approach in treatment plan design.

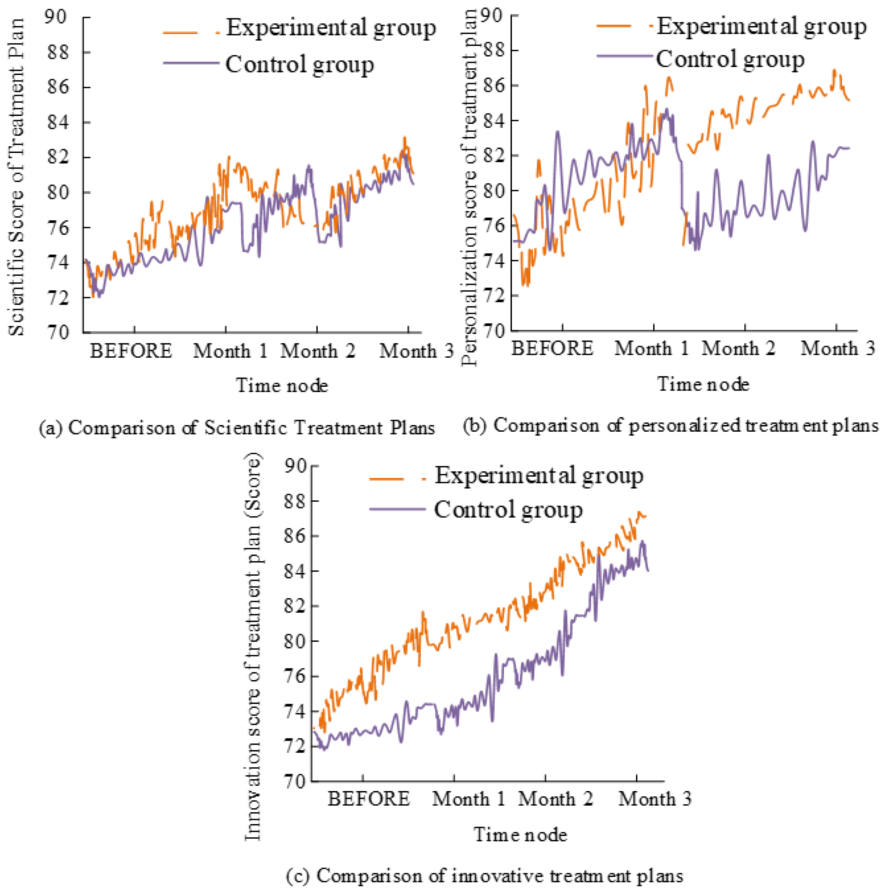

Figure 2. Specific level of change in the overall treatment plan design ability for two groups of epilepsy.

3.5. Comparison of satisfaction between two groups of students with PBL mode

In the context of multidisciplinary collaborative teaching, the correlated results of the problem-based learning (PBL) model applied in epilepsy education are shown in **Table 4**. In **Table 4**, there is no statistically significant difference in student satisfaction scores between the two groups before the intervention ($P > 0.05$). After three months of PBL teaching, the overall satisfaction of both groups increased, with the experimental group's satisfaction improving significantly more than the control group's ($P < 0.05$). Specifically, the experimental group's score for acceptance of teaching methods was 3.21 ± 0.45, compared to the control group's 2.89 ± 0.53 (p = 0.002); for teaching interactivity, the experimental group's score was 3.30 ± 0.42 versus the control group's 2.95 ± 0.49 (p = 0.001); for interdisciplinary knowledge integration, the experimental group scored 3.45 ± 0.38 while the control group scored 3.05 ± 0.51 (p = 0.004); for improvement in clinical thinking ability, the experimental group scored 3.55 ± 0.41 versus the control group's 3.20 ± 0.48 (p = 0.013); and for overall satisfaction with treatment plan design, the experimental group scored 3.60 ± 0.39 compared to the control group's 3.15 ± 0.46 (p = 0.005). These data indicate that the experimental group students showed greater improvements in acceptance of teaching methods, teaching interactivity, and interdisciplinary knowledge integration compared to the control group ($P < 0.05$). Additionally, the experimental group students exhibited a more significant enhancement in clinical thinking ability ($P < 0.05$). The experimental group students also demonstrated significantly higher satisfaction with the overall design of epilepsy treatment plans than the control group, with the difference being statistically significant ($P < 0.05$).

Table 4. Comparison of student satisfaction with the PBL model between two groups.

Variable	Experimental Group (*n* = 60) (After Intervention)	Control Group (*n* = 60) (After Intervention)	*P*-value
Teaching Method Acceptance	3.21 ± 0.45	2.89 ± 0.53	0.002*
Teaching Interactivity	3.30 ± 0.42	2.95 ± 0.49	0.001*
Interdisciplinary Knowledge Integration	3.45 ± 0.38	3.05 ± 0.51	0.004*
Clinical Thinking Ability Improvement	3.55 ± 0.41	3.20 ± 0.48	0.013
Overall Satisfaction with Treatment Plan Design	3.60 ± 0.39	3.15 ± 0.46	0.005*

Note: Data are presented as mean ± standard deviation. * indicates $P < 0.05$, which is statistically significant.

Figure 3 shows the correlation between student satisfaction with the PBL model and improvement in clinical thinking ability, consisting of three lines representing the overall student sample, the experimental group with satisfaction scores ≥ 80, and the experimental group with satisfaction scores < 80. The X-axis represents the PBL model satisfaction score, while the Y-axis represents the improvement in clinical thinking ability score. In **Figure 3**, there is a significant positive correlation between PBL model satisfaction and improvement in clinical thinking ability ($P < 0.05$). When the satisfaction score reaches 80, students with high satisfaction show an improvement score of approximately 85 in clinical thinking ability, while those with low satisfaction only reach a score of 70, demonstrating a significant advantage in improvement for high-satisfaction students. This indicates that high satisfaction with the PBL teaching model significantly enhances students' clinical thinking ability, particularly in interdisciplinary collaboration and problem-solving skills.

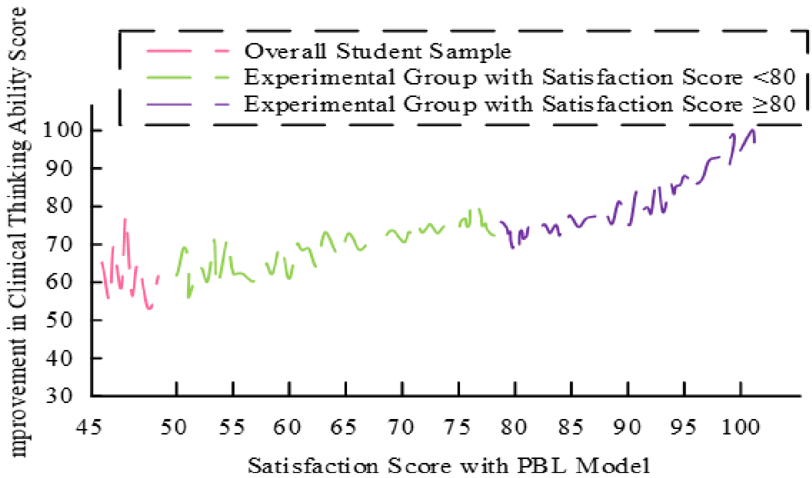

Figure 3. The correlation between students' satisfaction with PBL mode and the improvement of clinical thinking ability.

3.6. Comparison of clinical exam scores between two groups of students

Figure 4 shows the changes in clinical exam scores between the experimental and control groups. Each data point in the figure represents the score of an individual student in different exam sections. In **Figure 4a**, the experimental group scores are clearly higher than those of the control group, with data points concentrated in the higher score range, around 85, while the control group scores are concentrated in a lower range, around 65. **Figure 4b** also shows higher scores for the experimental group, with data points concentrated around 83, while the control group scores are concentrated around 68. Statistical analysis indicates that the score differences between the two groups are significant ($P < 0.05$). These results suggest that the PBL teaching model, by enhancing interdisciplinary collaboration and clinical thinking training, significantly improves students' clinical abilities and overall knowledge integration.

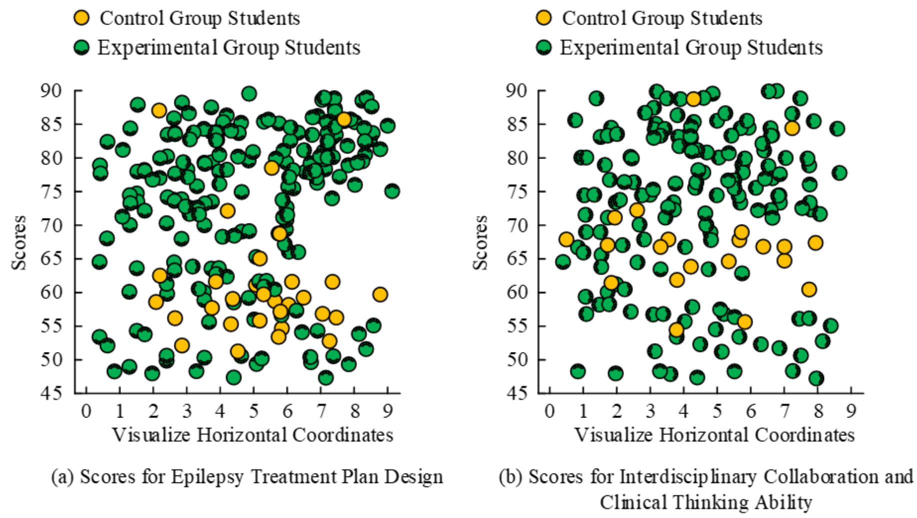

Figure 4. Comparison of clinical exam scores between experimental group and control group students.

3.7. Comparison of clinical skill performance between two groups

Table 5 presents the differences in clinical skills performance between the experimental group and the control group students during a three-month PBL-based teaching process. The experimental group scored significantly higher than the control group in epilepsy diagnosis accuracy, treatment plan design, interdisciplinary collaboration, clinical thinking ability, innovation in case discussion, clinical decision-making ability, and history taking and analysis, with all differences showing statistical significance ($P < 0.05$). Specifically, the experimental group scored 4.2 ± 0.5 in epilepsy diagnosis accuracy, which was significantly higher than the control group's score of 3.8 ± 0.6 ($p = 0.032$); in treatment plan design, the experimental group scored 4.1 ± 0.4, while the control group scored 3.6 ± 0.5 ($p = 0.045$); in interdisciplinary collaboration, the experimental group scored 4.3 ± 0.5, compared to the control group's score of 3.7 ± 0.6 ($p = 0.021$); in clinical thinking ability, the experimental group scored 4.0 ± 0.4, higher than the control group's 3.5 ± 0.5 ($p = 0.040$); in innovation in case discussion, the experimental group scored 4.1 ± 0.5, while the control group scored 3.6 ± 0.5 ($p = 0.038$); in clinical decision-making ability, the experimental group scored 4.0 ± 0.4, compared to the control group's 3.7 ± 0.6 ($p = 0.028$); and in history taking and analysis, the experimental group scored 4.2 ± 0.5, significantly higher than the control group's 3.8 ± 0.6 ($p = 0.033$). These data indicate that the PBL model significantly enhanced students' clinical abilities, particularly in improving diagnostic and treatment skills, fostering interdisciplinary collaboration, and enhancing clinical thinking and decision-making capabilities.

Table 5. Differences in clinical skill performance.

Variable	Experimental Group (n = 60)	Control Group (n = 60)	P-value
Epilepsy Diagnosis Accuracy	4.2 ± 0.5	3.8 ± 0.6	0.032*
Treatment Plan Design Ability	4.1 ± 0.4	3.6 ± 0.5	0.045*
Interdisciplinary Collaboration	4.3 ± 0.5	3.7 ± 0.6	0.021*

Table 5. (*Continued*).

Variable	Experimental Group (n = 60)	Control Group (n = 60)	P-value
Clinical Thinking Ability	4.0 ± 0.4	3.5 ± 0.5	0.040*
Innovation in Case Discussion	4.1 ± 0.5	3.6 ± 0.5	0.038*
Clinical Decision-Making Ability	4.0 ± 0.4	3.7 ± 0.6	0.028*
History Taking and Analysis Ability	4.2 ± 0.5	3.8 ± 0.6	0.033*

Note: Data are presented as mean ± standard deviation. * indicates $P < 0.05$, which is statistically significant.

4. Conclusion

In the field of medical education, the PBL (Problem-Based Learning) model has been widely applied in multidisciplinary collaborative teaching. Research has explored the application of the PBL model in epilepsy teaching, with a focus on evaluating its effectiveness in enhancing students' clinical thinking, teamwork, and interdisciplinary collaboration skills. The introduction of multidisciplinary collaborative teaching in epilepsy education is an important initiative aligned with the modern reform of medical education. Epilepsy, as a complex neurological disorder, involves a variety of etiologies, complex clinical manifestations, and diverse treatment approaches, encompassing multiple disciplines such as neurology, psychology, pharmacology, and nursing. The traditional single-discipline teaching model is insufficient to comprehensively address these knowledge points, making the introduction of multidisciplinary collaborative teaching particularly significant. The PBL model emphasizes student-centered learning, guiding students to learn independently through specific clinical cases, fostering their ability to identify, analyze, and solve problems.

Research findings indicate that the PBL model can significantly improve students' mastery of clinical knowledge and practical skills in epilepsy. Students in the experimental group scored significantly higher than those in the control group in terms of diagnostic accuracy and treatment plan design for epilepsy, suggesting that teaching through the PBL model enables students to gain a deeper understanding of the complex pathology and clinical management strategies of epilepsy. However, this study had some limitations. The research period was relatively short (9 months), which means that the long-term impact of the PBL model on students' clinical decision-making and problem-solving skills remains unclear. Furthermore, the sample size of 120 students may not be large enough to allow for generalizability to a wider population. Future studies should aim to expand the sample size and extend the follow-up period to better assess the long-term effects of the PBL model in both learning and clinical practice. Data analysis showed that the experimental group scored 4.2 ± 0.5 in diagnostic accuracy, compared to 3.8 ± 0.6 in the control group ($p = 0.032$). In terms of treatment plan design, the experimental group scored 4.1 ± 0.4, while the control group scored 3.6 ± 0.5 ($p = 0.045$). These results are consistent with prior research, which shows that problem-based learning can effectively enhance students' clinical decision-making and interdisciplinary integration abilities. Through the PBL model, students can better grasp the pathophysiology, clinical manifestations, and treatment methods of epilepsy, thus enabling them to make more confident and accurate diagnoses and decisions in real clinical situations. The PBL model emphasizes independent learning and teamwork, with students in the experimental group showing markedly better performance in interdisciplinary collaboration than those in the control group. In the simulated case discussion session, 72% of students in the experimental group were able to propose comprehensive treatment plans that integrated knowledge from neurology, psychology, pharmacology, and other disciplines, highlighting the positive role of interdisciplinary collaboration in epilepsy treatment. Specifically, the experimental group scored 4.3 ± 0.5 in interdisciplinary collaboration participation, while the control group scored 3.7 ± 0.6 (p = 0.021). This difference reflects the significant advantage of the PBL model in cultivating students' teamwork and interdisciplinary collaboration skills. In traditional teaching models, students are often limited to a single discipline's knowledge framework, but under the PBL model, they are required to integrate knowledge from different fields and develop comprehensive treatment plans. This not only enhances students' ability to integrate different subjects but also strengthens their interdisciplinary collaboration skills.

The PBL model also emphasizes students' active learning. In traditional teaching models, students often passively receive knowledge, whereas the PBL model requires them to actively search for information, analyze problems, and propose solutions. This learning approach not only improves students' independent learning abilities but also enhances their critical thinking and innovative capabilities. Students in the experimental group scored significantly higher in independent learning ability assessments compared to the control group, indicating that the PBL model has a clear advantage in fostering students' autonomy in learning [11,12]. During the learning process, students focus more on independent exploration and thinking, and their proposed diagnostic and treatment plans are often more innovative and diverse. To implement the PBL model more effectively in epilepsy education, certain resources are essential. For instance, integrating biomechanics into the curriculum requires access to specialized teaching materials, including biomechanical models and simulation tools. Teachers will also need professional development opportunities to enhance their skills in guiding interdisciplinary collaboration and case-based learning. Specific training programs focused on facilitating discussions among faculty from neurology, pharmacology, and other relevant disciplines will be vital. Multidisciplinary collaborative PBL teaching helps improve students' interdisciplinary collaboration abilities. In epilepsy education, students need to understand and apply knowledge from disciplines such as neurobiology, pharmacology, and psychology, integrating this knowledge into clinical practice. Our research found that students in the experimental group showed clear advantages in interdisciplinary knowledge integration abilities [13]. They were able to better understand and apply knowledge from different disciplines, proposing more comprehensive and reasonable treatment plans. This suggests that the PBL model fosters students' global thinking, encouraging them to pay more attention to interdisciplinary collaboration and integration in clinical decision-making. Moreover, the role of the teacher in the PBL model shifts from a traditional knowledge transmitter to that of a facilitator. To facilitate this transition, teachers must undergo continuous training in PBL methodologies, case development, and interdisciplinary teaching techniques. It is also important to ensure that teachers have the resources and time to prepare high-quality, multidisciplinary case studies. Teachers must possess broader subject knowledge to guide students in integrating and applying knowledge from different disciplines. Moreover, teachers need higher levels of teaching organization and management skills to effectively organize and guide students in group discussions and case analyses [14,15]. Therefore, the role of the teacher in the PBL teaching model shifts from that of a traditional knowledge transmitter to that of a facilitator and guide, which demands a higher level of comprehensive competence from teachers. In practical teaching, the implementation of the PBL model faces several challenges. The preparation of teaching resources is one such challenge, as PBL teaching requires a large number of cases and materials, and teachers must dedicate considerable time and effort to preparing these resources. Students' adaptation to learning is another issue, as some may not be accustomed to this active learning model and may need more guidance and support from teachers at the beginning. Multidisciplinary collaborative PBL teaching also requires close cooperation and coordination among teachers from different disciplines, which places higher demands on teaching organization and management. Despite these challenges, the study demonstrates that the multidisciplinary collaborative PBL model has significant advantages in epilepsy education. This teaching model not only helps students better master knowledge related to epilepsy but also enhances their clinical thinking, teamwork, and interdisciplinary collaboration abilities, providing valuable insights and reference for future medical education reform. However, the study does have certain limitations. The sample size was relatively small, and the research period was short. Future studies should aim to expand the sample size and extend the follow-up period to verify the long-term effects of the PBL model in both learning and clinical practice. An important direction for future research will be how to more effectively integrate interdisciplinary teaching resources and clinical experience to better address the management of complex diseases in clinical settings.

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