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Review

Problem-Based Learning and Simulation-Based Learning in Clinical Endocrinology Education: Applications and Future Directions

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Abstract

Diagnosing and treating endocrine diseases is a highly complex endeavor requiring advanced clinical reasoning, decision-making, and practical skills. However, traditional medical teaching approaches are unable to fully cater to the cultivation of these skills among residents. Thus, reforming the current teaching model utilized in clinical endocrinology education by introducing problem-based learning (PBL) and simulation-based learning (SBL) methods is imperative. This article aims to review the current application and research progress of PBL and SBL in clinical endocrinology education and explore their potential for synergistic integration. This narrative review synthesizes findings from peer-reviewed literature identified through searches of PubMed, CNKI, and Web of Science databases. The literature was thematically analyzed to summarize implementation models, educational outcomes, and integration strategies across different training stages. Problem-based learning helps deepen the understanding of disease mechanisms and cultivate systems thinking, while simulation-based learning enables healthcare professionals to develop essential skills through practice in controlled, realistic settings. Both methods, when used individually, demonstrate effectiveness in improving learners' knowledge acquisition, skill confidence, and satisfaction, despite the presence of limitations. Research indicates that combining PBL and SBL may more effectively promote the overall development of clinical competence. In conclusion, PBL and SBL are effective methods for improving clinical endocrinology education, and their complementary advantages suggest that synergistic application represents a promising future direction. However, applying this technique necessitates revision of curriculum, more intense teacher training, and the development of new evaluation systems centered on clinical competence.

Keywords: problem-based learning; simulation-based learning; endocrinology; medical education

1. Introduction

Endocrinology is a highly specialized discipline requiring integration of complex physiological mechanisms with long-term clinical management [1]. The endocrine system maintains the homeostasis of the internal environment through fine feedback regulation. Its dysfunction often manifests as multi-system and multi-level clinical problems, making endocrine diseases highly complex and dynamic in the process of diagnosis and treatment [2]. Therefore, endocrinology in clinical practice particularly emphasizes the concept of holistic assessment and individualized diagnosis and treatment, focusing not only on the standardized diagnosis and drug treatment of diseases, but also on the implementation of long-term follow-up, risk assessment, and health management strategies. In light of this clinical consideration in a real-world setting, the standardized education and training for resident physicians in endocrinology are designed to cultivate clinicians' ability to systematically grasp relevant knowledge and techniques of diagnosis and treatment of endocrine diseases [3]. The training content covers a wide range of common and complex diseases, including diabetes and its complications, metabolic syndrome, hyperuricemia, obesity, thyroid diseases, and pituitary and adrenal-related diseases. It requires resident physicians to possess not only a solid theoretical foundation but also strong clinical reasoning, comprehensive decision-making, and doctor–patient communication skills [4,5,6]. However, in the traditional teaching model, knowledge transmission is often overemphasized, without sufficiently developing residents' clinical reasoning and problem-solving abilities, thereby resulting in a gap between educational outcomes and clinical competence.

Traditional lecture-based teaching, while valuable for systematic knowledge delivery, is a passive delivery method that lacks an authentic clinical context [7]. In addition, traditional training models rely heavily on clinical demonstrations and experience accumulation, and their applicability and sustainability are somewhat limited in the context of the increasing awareness of patient safety [8]. With the continuous updating of medical education concepts, learner-centered and competency-oriented teaching models are gradually gaining attention. Problem-based learning (PBL) is a clinical problem-centered method that cultivates clinical thinking and self-learning abilities by guiding learners to actively consult materials, analyze information, and conceptualize solutions in real or simulated problem situations [9]. Meanwhile, simulation-based learning (SBL) offers a new approach to resident competency training in managing complex or high-risk situations through the use of highly realistic clinical scenarios that facilitate repeated practice of clinical procedures and decision-making within a safe and controllable environment [10].

For endocrinology, which demands both mechanistic understanding and clinical judgment, PBL and SBL are highly complementary to each other [11,12]. Although they have been examined individually, systematic efficacy analyses of their amalgamation, as well as the implications for competency-based training, remain scarce. Thus, this review aims to synthesize current evidence on PBL and SBL in endocrinology education, critically evaluate their strengths and limitations, and examine the potential of their synergistic application in curriculum development and the inherent practical challenges.

Given the heterogeneous nature of existing studies and the exploratory stage of integrated PBL–SBL applications in endocrinology, this article presents a narrative review designed to synthesize current knowledge, identify research gaps, and propose future directions, rather than a formal systematic review with meta-analysis.

To identify relevant literature, a systematic search in the PubMed (https://pubmed.ncbi.nlm.nih.gov/), CNKI (https://www.cnki.net/), and Web of Science databases (https://www.webofscience.com/) for articles published since their inception up until April 2026 was conducted. Search terms included combinations of "problem-based learning" OR "PBL", "simulation-based learning" OR "SBL" OR "simulation", "endocrinology", "medical education", and "resident training" OR "postgraduate training". Reference lists of retrieved articles were also manually screened. Due to the heterogeneity of study designs, educational interventions, and outcome measures identified in the literature, a narrative synthesis approach was adopted. Findings were summarized and integrated thematically according to teaching methods (PBL, SBL, and combined approaches) and training stages (undergraduate, residency, and continuing education).

2. Theoretical Basis of PBL and Its Application Progress in Clinical Education

2.1 Theoretical Basis and Advances in the Applications of PBL in Medical Education

Problem-based learning (PBL) was pioneered at McMaster University in Canada during the 1960s and 1970s and has since become widely adopted in medical education worldwide [13]. As a learner-centered approach, PBL is an active learning approach that organizes learning activities around authentic clinical problems and guides knowledge acquisition through hypothesis generation, information analysis, and problem-solving [14]. Although PBL has been utilized in medical education for a long time, its theoretical basis was not systematically explained at the beginning. The implementation of PBL requires curriculum development at the initial stage of the teaching process, which substantially requires the teaching and practical experiences of the professors, rather than a clear educational psychology framework. With the widespread adoption in different countries and disciplines, researchers in the field of education have been able to decipher the underlying mechanisms of PBL from the perspective of cognitive psychology and learning science. Among the theoretical frameworks proposed in the literature, Barrows's PBL objective framework is widely accepted. It emphasizes that, in medical education, PBL should simultaneously support knowledge organization within clinical contexts, foster clinical reasoning, develop self-directed learning skills, and enhance learning motivation [15]. This framework provides relatively clear analytical dimensions for subsequent research and has become an important reference for evaluating the quality of PBL implementation.

From a constructivist perspective, learning is viewed as an active process of knowledge construction rather than passive reception; PBL aligns with this view by positioning learners as active problem-solvers who integrate new information with existing cognitive frameworks through collaborative inquiry [16]. This theoretical lens is particularly relevant to endocrinology education, where understanding complex feedback systems (e.g., hypothalamic–pituitary–adrenal axis, glucose-insulin homeostasis) requires learners to continuously revise and integrate knowledge across multiple physiological systems rather than memorizing isolated facts. At the same time, the clinical relevance embedded in problem scenarios improves the comprehensibility and transferability of learning content, thereby promoting the application of newly acquired knowledge in real clinical settings [17,18].

In medical and nursing education, the PBL pedagogical framework was initially applied to only a single course but has since been integrated into the curriculum design across multiple disciplines and stages. Some educational programs combine PBL with skills training, clinical practice, and evidence-based medicine teaching to facilitate learners' understanding of the entire disease trajectory, from onset and diagnosis to long-term management, within a continuous case thread [19]. This vertical teaching model emphasizes the synchronous theoretical knowledge acquisition and development of clinical decision-making skills, providing favorable conditions for cultivating the ability to manage complex diseases. For disciplines like endocrinology, which require integration of mechanistic understanding with complex clinical decision-making, the "problem-first" and "context-driven" concepts advocated by PBL are particularly relevant. For instance, in managing a patient with type 2 diabetes and chronic kidney disease, where multiple factors such as glucose metabolism,

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renal drug clearance, cardiovascular risk, dosages of anti-hyperglycemic agents, patient preferences, adherence barriers, and cost should be collectively considered. Under a well-designed PBL framework for this scenario, learners are required to navigate these competing considerations iteratively, adjusting treatment decisions as new information unfolds—whether weighing metformin continuation against renal function, selecting glucagon-like peptide-1 (GLP-1) receptor agonists based on cardiovascular benefit profiles, or determining when to initiate insulin as the disease progresses. This mirrors the real-world complexity of endocrine practice, where treatment decisions must be dynamically tailored to individual patient circumstances. By engaging with such multifaceted problems, learners develop not only mechanistic understanding but also the ability to synthesize evidence, manage uncertainty, and justify clinical judgments—skills that are difficult to cultivate through traditional lecture-based teaching alone.

2.2 Advances in the Application of PBL in Clinical Endocrinology Education

Supported by the above-mentioned theoretical framework and educational philosophy, PBL has been gradually introduced into different stages of clinical endocrine education. Its implementation and efficacy in specific teaching scenarios have also become the focus of research in recent years. In undergraduate and early clinical teaching, PBL commonly uses cases based on typical endocrine diseases, such as diabetes, thyroid dysfunction, and metabolic syndrome. These cases present the patient's symptom progression, laboratory findings, and imaging results in stages, encouraging learners to progressively develop diagnostic hypotheses and formulate preliminary management plans through group discussions [20]. Walters [11] suggests that combining PBL with lectures in endocrine courses can significantly improve students' satisfaction with the course and their learning enthusiasm, as measured by a locally developed post-course questionnaire. Zhao et al. [21] combined PBL with case-oriented learning in the teaching situation. Their findings indicate that PBL encourages learners to consult materials before class and develop a clearer understanding of the course content related to endocrine diseases. Compared with traditional teaching methods, it is more effective in fostering the early development of clinical thinking skills. However, the assessment of "clinical thinking" in this study relied on non-validated instruments, and the lack of long-term follow-up leaves it unclear whether these gains persist beyond the immediate course period.

In practice, the application of PBL in endocrinology education typically centers on representative conditions with well-defined disease mechanisms, relatively standardized diagnostic and therapeutic pathways, and strong potential for integrative analysis. Hyperthyroidism is one of the conditions with such attributes that has been constantly used as the teaching topic under the PBL framework in recent years. For instance, a longitudinal study of hyperthyroidism integrating foundational science with clinical aspects has been consistently exemplified within a series of PBL studies involving resident physicians. A pre- and post-teaching comparison revealed that the residents trained within the PBL framework achieved significant gains in theoretical knowledge, self-directed learning, and clinical problem-solving, along with improvements in clinical thinking ability and the ability to share learning outcomes [22]. However, these aspects were assessed using non-validated rating scales completed by preceptors who were aware of the study objectives, introducing the potential for expectancy bias. Furthermore, the study lacked a control group, making it impossible to determine whether these perceived improvements were attributable to PBL or to routine clinical maturation. In summary, teaching typical cases such as thyroid diseases within the PBL framework enables the transformation of residents from knowledge recipients to problem-driven analysts. Collectively, these studies suggest that this transformation is the key mechanism underlying improvements in clinical reasoning and self-directed learning, highlighting the importance of prioritizing the training of specific abilities at different stages and providing support for improving the overall capabilities of resident physicians.

In addition to residency training, PBL has been increasingly incorporated into undergraduate endocrinology clerkships and is progressively integrated with other instructional models in course design and delivery. A domestic study demonstrated the integration of the Bridge-In, Objective, Pre-assessment, Participatory Learning, Post-assessment and Summary (BOPPPS) teaching framework with the PBL into the endocrinology clinical clerkship, which is grounded in a structured process of "course introduction – familiarization with learning objectives – quiz prior to lesson – participatory learning – test after lesson – revision" to encourage students to actively participate in discussions and develop their decision-making skills through problem-based scenarios [23]. Both student self-evaluations and teacher assessments favored the intervention group across multiple domains, including classroom participation, history taking, treatment planning, and doctor–patient communication. Notably, the use of both self-reported and observer-rated outcomes partially mitigates same-source bias. However, the teacher evaluators were not blinded to group allocation, which may have introduced detection bias. Additionally, as the study's primary endpoints were measured immediately after the intervention, it remains unclear whether these observed effects persist beyond the immediate learning environment or translate into improved clinical performance.

Therefore, employing the PBL framework in endocrinology teaching allows for the benefits of problem-driven learning while enhancing classroom efficiency and learning outcome attainment. Translating this into practice requires attention to several key elements of PBL organization. Case design should prioritize clinical scenarios that capture the complexity of endocrine decision-making. For example, a patient with newly diagnosed hyperthyroidism may require consideration of multiple treatment options—antithyroid drugs, radioactive iodine, or surgery—each with distinct efficacy profiles, side effect risks, and implications for long-term management. Such scenarios require learners to weigh competing evidence, consider patient preferences, and anticipate how initial choices may shape future options. Cases should be structured in stages, with information revealed progressively to simulate diagnostic uncertainty. The educator's role also shifts from content delivery to facilitation, guiding inquiry and probing reasoning while maintaining productive group dynamics without providing direct answers. This requires knowing when to intervene and what questions to ask. Learners should produce structured outputs—reasoning maps, differential diagnosis tables, or management plans with justifications—that externalize their thinking and provide tangible material for feedback. Finally, evaluation must extend beyond factual recall to assess clinical reasoning itself, through rubric-based analysis of case work, peer evaluation of group contribution, or reflective essays on decision-making processes. By attending to these structural elements, educators can move PBL from a general pedagogical philosophy to a replicable instructional strategy that systematically promotes the development of clinical reasoning abilities among endocrinology learners.

Compared with undergraduate education and clinical training, the systematic application of PBL in the standardized training of endocrinology residents remains in the exploratory stage. Some studies suggest that PBL helps shift away from the traditional teacher-centered model, enabling resident physicians to move from passive recipients of information to problem-driven learners, and thereby promotes the cultivation of clinical reasoning, self-directed learning, and teamwork skills [24]. However, according to existing literature, implementation of PBL in the standardized instructional contents for endocrinology courses remains challenging due to limited scope for application and inadequate promotion of this pedagogical approach. On the one hand, some resident physicians and professors do not fully understand and embrace the PBL concept, and still rely more on traditional lecture methods; on the other hand, the effective implementation of PBL puts forward higher requirements for teaching resources, including design of more intellectual problems, extended teaching time, suitable learning environments, and relevant teaching experience, despite the fact that certain resident training centers are unable to fully meet the above requirements. In addition, the current standardized training system for endocrinology residents remains largely oriented toward knowledge transmission in both curriculum design and assessment methods, with insufficient emphasis on the clinical reasoning and comprehensive competency development emphasized by PBL, which to some extent limits its deeper implementation.

Overall, existing research on the application of PBL in endocrinology education is characterized by a "disease-driven" and "stage-based integration" approach. In most PBL-based lessons, endocrine conditions with relatively well-defined mechanisms and standardized treatment pathways, such as diabetes and thyroid diseases, are utilized as case studies to help learners build a systematic clinical reasoning framework. In terms of instructional design, PBL is increasingly being combined with other teaching approaches, such as the BOPPPS model and case-based learning (CBL), across different stages of clinical practice and residency training, aiming to strike a balance between problem-driven learning and teaching efficiency. However, most of these studies focus on short-term educational outcomes, such as academic performance and learner satisfaction, and provide limited high-quality follow-up evidence on whether and how PBL influences residents' long-term clinical decision-making patterns and their ability to manage atypical cases. Furthermore, it remains highly crucial to systematically integrate PBL into the existing residency training system, which is primarily structured around departmental rotations and exit assessments, rather than as an isolated "teaching intervention", to ensure its sustainable implementation. Future efforts should therefore focus on more organically integrating PBL into the endocrinology residency curriculum, guided by clearly defined training objectives, and enhancing its efficacy in clinical competence through improved allocation of teaching resources and faculty development.

3. Theoretical Basis of SBL Methods and Their Application Progress in Endocrinology Education

3.1 Theoretical Basis and Advances in Medical Education Applications of SBL

As modern medicine gradually evolves toward higher risk, greater complexity, and stronger reliance on teamwork, SBL methods have progressively developed and become an important part of the medical education system. The origin of medical simulation training can be traced back to the 1960s, when human models (such as Resusci Anne) developed for teaching cardiopulmonary resuscitation were used to replace human patients for demonstration, marking the early application of simulation technology in medical training [25]. With the continuous evolution of medical education concepts and technical means, the function of simulation has gradually expanded from single skill training to the systematic cultivation of clinical decision-making, emergency response, and teamwork ability [26]. Through SBL, realistic clinical scenarios are simulated to enable safe, repeatable practice of clinical decision-making and technical skills, integrating knowledge acquisition with skill development and reflective learning [27]. Numerous studies have shown that simulation training can not only improve learners' operational skills and behavioral performance but also facilitate improvement of clinical quality and patient outcomes. Therefore, it is regarded as a form of patient safety–oriented educational intervention [28,29].

In the medical education system, the application of SBL is highly diversified. It can be used for basic skills training as well as for the cultivation of complex clinical decision-making and multidisciplinary collaboration. Common simulation forms include virtual reality systems, highly realistic mannequins, standardized patients, task training models, and situational case exercises [30]. Different simulation tools vary in their levels of fidelity, operational complexity and instructional objectives. Educators can flexibly combine them according to the learners' levels, and teaching needs to support a progressive development of competencies. It is worth noting that while emphasizing technical ability training, SBL also provides an important platform for the cultivation of non-technical abilities. In real-world clinical settings, communication failures, unclear role division, and insufficient team collaboration are often important causes of medical errors, and these factors are difficult to systematically evaluate and intervene in traditional teaching environments. Through multidisciplinary, role-based participation, simulation-based teaching allows learners to directly experience how team interaction influences diagnostic and therapeutic outcomes in scenario-based exercises, and to identify key behavioral factors affecting team performance through structured feedback. This synchronous training of technical skills and behavioral performance is considered an important way to improve the overall operating efficiency of the medical system. From the perspective of educational assessment, SBL has gradually become one of the important approaches for medical competence assessment. Compared with the previous assessment methods that mainly consist of written tests or case reports, simulation-based assessment can more accurately evaluate learners' decision-making ability, operational standardization, and adaptability under pressure [28].

3.2 Advances of SBL Applications in Clinical Endocrinology Education

In endocrinology and other internal medicine fields, the potential advantages of SBL are particularly prominent. The diagnosis and treatment of endocrine diseases often involve chronic disease management, multi-system assessments, and long-term follow-up decisions. Its core competencies include not only drug selection and indicator interpretation but also risk assessment, communication and coordination, and comprehensive judgment. By simulating typical or complex case scenarios, learners can repeatedly practice diagnostic and treatment procedures and decision-making processes in a safe environment; therefore, the SBL approach can address training gaps resulting from limited clinical practice opportunities. Compared to traditional simulations that primarily emphasize procedural skills, scenario-based simulation places greater emphasis on cognitive decision-making and teamwork, closely aligning with the competency development goals of endocrinology training. In recent years, the application of SBL in endocrinology education has expanded from procedural skills training to include clinical decision-making, interdisciplinary communication, and comprehensive competency development, exhibiting diverse implementation forms at different stages of training.

Simulation-based learning (SBL) has been systematically used to provide practice opportunities for complex clinical scenarios that are rarely encountered in real practice or allow minimal margin for error, and because of these benefits, its application in postdoctoral training in endocrinology has demonstrated clear educational value [31]. In Yu et al.'s study [31], SBL-trained researchers scored significantly higher in the annual theoretical assessment than those receiving regular training. This assessment is a high-stakes, summative examination administered to all postdoctoral trainees, comprising multiple-choice and short-answer questions developed by a central examination committee. The use of this objective, standardized outcome measure strengthens the evidence base compared with studies relying solely on self-reported data. However, theoretical knowledge, while important, represents only one dimension of clinical competence, and this assessment primarily evaluates knowledge recall rather than clinical performance. Whether SBL-trained clinicians demonstrate superior skills in real-world patient care remains an open question that this study design could not address.

In addition to traditional face-to-face simulations, digital and virtual forms of SBL are gradually being applied in endocrinology education, expanding the accessibility and flexibility of simulation teaching. The Simulation via Instant Messaging–Birmingham Advance (SIMBA) model is a simulation method hinged on social media platforms. It constructs a virtual diagnosis and treatment scenario using anonymized real-case records. During the simulation, trainees interact with a moderator to make diagnostic and management decisions, followed by a debriefing in which an endocrinology specialist provides guideline-based explanations [32]. In a study by Melson et al. [32], SIMBA was applied to the teaching of endocrinology topics, covering complex conditions such as craniopharyngioma, acromegaly, Cushing's disease, and giant prolactinoma. The study showed that trainees' self-confidence in the management of the above diseases was significantly improved after the simulation, and their acceptance of the course format and participation experience were highly rated [32]. Based on this, it can be preliminarily inferred that this model, through a low-cost and remotely accessible approach, enables trainees to repeatedly practice the analysis and decision-making of complex endocrine cases without risk to patients, offering a novel approach for the application of SBL in continuing medical education and cross-regional training.

In the field of diabetology, SBL is widely used in teaching scenarios pertaining to routine management as well as emergency and critical care. Virtual reality technology is used to create simulated training environments for diabetic emergencies, allowing trainees to immerse themselves in clinical scenarios such as diabetic ketoacidosis and hyperosmolar hyperglycemic. Pokrywka et al.'s research [33] suggests that trainees who participate in such virtual simulations demonstrate improved competence and confidence in managing diabetic emergencies. These findings indicate that SBL is particularly suitable for endocrine diseases that require long-term management decisions and dynamic adjustment of treatment plans, as it helps learners understand the clinical consequences of different decision-making pathways.

From existing applications, the value of SBL in endocrinology education has transcended simple skills training, expanding toward decision-making simulation and teamwork training. Its application spans multiple learner levels, from medical students to practicing clinicians, and demonstrates unique advantages in complex case analysis, interdisciplinary collaboration, and the acquisition of new clinical techniques. Whether through virtual reality scenarios for managing diabetic emergencies or complex case discussions simulating multidisciplinary consultations, the core purpose is to provide learners with a risk-free "decision-making testing ground". However, it should be noted that most current research still relies on learners' self-reported scores (such as confidence and satisfaction) and immediate assessment results as the primary endpoints. Whether excellent performance in the simulation environment can be fully translated into clinical competence in the real ward still requires validation through more rigorous translational medicine research.

4. Combined Application of PBL and SBL: Collaborative Model and Innovative Practices

Although both PBL and SBL have demonstrated independent value in medical education, the limitations of single-modality teaching have become increasingly apparent in practice. The effectiveness of PBL depends on the quality of discussion and learners' prior experience; without sufficient clinical context, learning may remain theoretical and may not effectively translate into practical skills [34,35]. SBL addresses this gap by providing a safe, simulated environment for repeatable skills practice and teamwork training [27]. However, SBL alone may lead learners to focus on operations without understanding underlying clinical reasoning, and without systematic reflection, knowledge transfer may be limited. These complementary limitations provide the rationale for their integration.

Building on the aforementioned shortcomings, recent medical education research has increasingly focused on the possibility of integrating PBL with SBL. From a pedagogical perspective, the two approaches are highly complementary in both learning objectives and functional positioning. PBL emphasizes problem-driven inquiry and cognitive construction, making it suitable for disease mechanism analysis, diagnostic and therapeutic strategy development, and the formulation of decision-making frameworks. In contrast, SBL focuses on situational experience and behavioral training, translating abstract cognitive processes into observable actions that can be assessed and improved through feedback. By placing PBL before or after simulation training, learners can be guided to formulate clear analytical hypotheses prior to entering the situation or to consolidate their understanding through reflective discussion after the situation. This sequencing enables dual reinforcement at both the cognitive and behavioral levels. Fig. 1 presents a conceptual framework for integrating PBL and SBL, illustrating the three core stages—problem analysis, situational experience, and reflective feedback—and their functional positioning. It is important to note that this figure depicts an idealized theoretical model rather than a rigid implementation flowchart. In practice, the boundaries between stages are fluid, and the framework operates in an iterative manner. The cognitive framework developed during problem analysis directly informs how learners engage with subsequent simulation activities (Stage 1–Stage 2), while insights gained through reflective feedback are carried forward to refine future problem analysis when new cases are encountered (Stage 3–Stage 1). Thus, although presented as a linear sequence for clarity, the model is designed to function as a dynamic learning cycle that evolves with each iteration.

In education related to endocrinology and chronic disease management, the integration of PBL and SBL is particularly important. Given their prolonged disease course and the availability of a diverse range of management options, diagnosing and treating endocrine disorders often relies on an excellent grasp of the underlying pathological mechanisms and evidence-based decision-making, in addition to patient education, adherence to follow-up plans, and collaboration with experts across professional disciplines. A single teaching model is often insufficient to address all of these competency dimensions simultaneously, whereas an integrated approach offers the potential for more comprehensive and systematic training. Existing studies have explored the synergistic application of PBL and SBL in diabetes nursing and case management. One study involving outpatient nurses integrated problem-based learning and simulation training into a multi-module education program focused on self-management education and case management for patients with type 2 diabetes [36]. The results indicated that comprehensive training, including PBL discussions and simulation exercises, helped improve nurses' capabilities in learning new knowledge and applying what

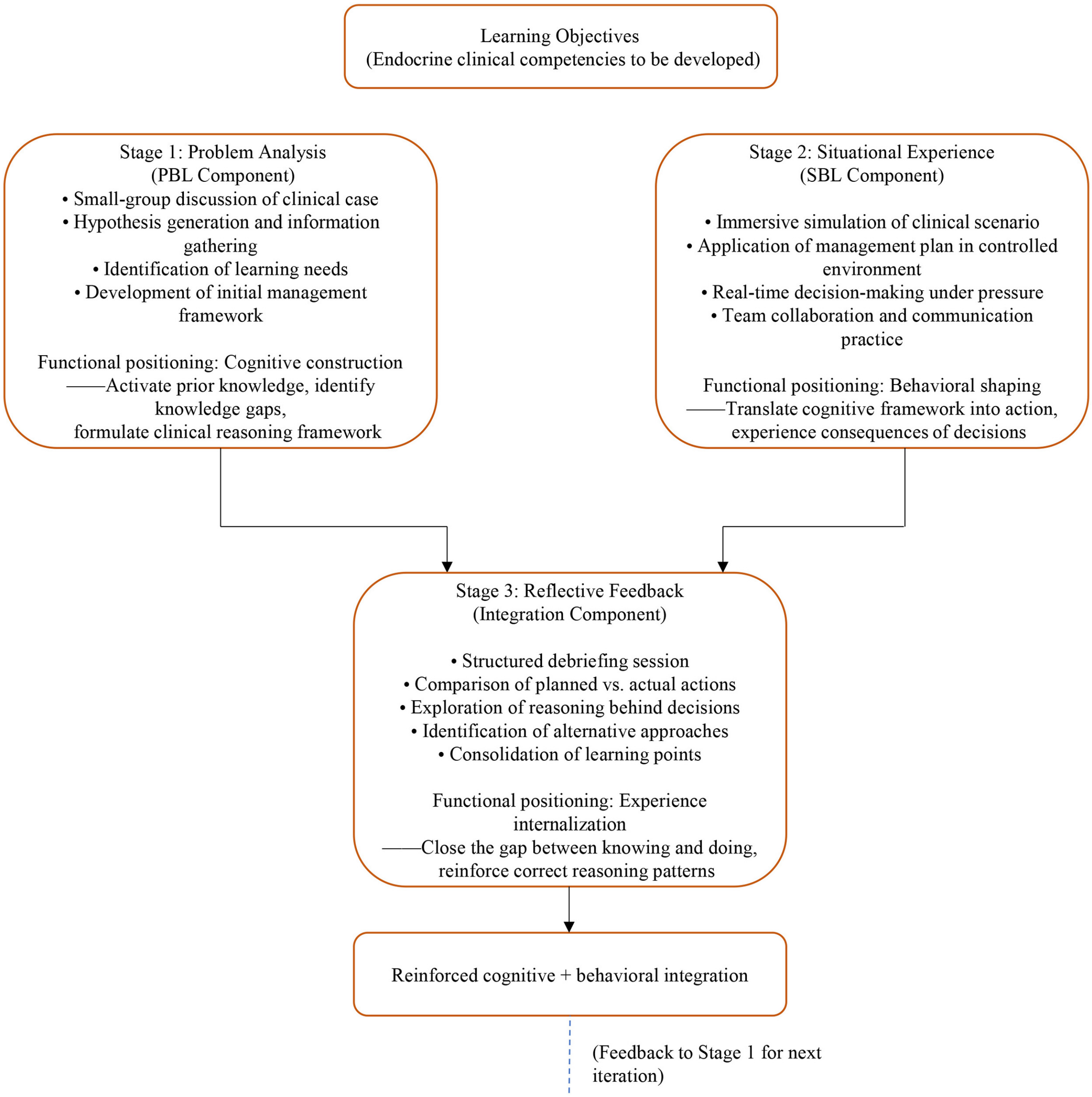

Fig. 1. Conceptual framework for integrated problem-based learning (PBL)–simulation-based learning (SBL) teaching.

they have learned, as reflected by post-training focus group interviews and satisfaction questionnaires. The simulation component provides a safe environment where the participants can engage in targeted competency exercises, while the problem-oriented discussions help them understand the theoretical basis and decision-making reasoning behind chronic disease management. Participants generally viewed this integrated model as an efficient and practical learning approach, suggesting that combining PBL and SBL can help improve the overall development level of chronic disease management-related capabilities.

In the standardized residency training of physicians, the teaching model combining scenario-based simulation and problem-based learning has been gradually introduced in endocrinology-related departments. In a study by Li et al. [37], senior endocrinology residents were trained using the integrated approach that combines scenario simulation with PBL. The results showed that the combined teaching model significantly improved the subjects' scores in both the theoretical examination and skills assessment groups compared to their counterparts receiving the traditional teaching intervention. In this study, skills were assessed using an objective structured clinical examination (OSCE) with standardized patient cases and validated checklists, and examiners were blinded to group allocation. The inclusion of both knowledge-based (written examination) and skills-

Table 1. Comparison of teaching models in endocrinology education.

Teaching model	Learning objectives	Applicable scenarios	Advantages	Limitations
Traditional teaching	Knowledge acquisition; mastery of factual content	Large-group lectures; theoretical foundation building	Efficient for delivering systematic knowledge; well-established; low resource demand	Passive learning; limited clinical reasoning development; poor transfer to practice
Problem-based learning (PBL)	Clinical reasoning; self-directed learning; teamwork	Small-group discussion of authentic clinical cases; exploration of disease mechanisms and management	Deepens understanding of disease processes; develops analytical thinking; promotes active learning	Time-intensive; dependent on facilitator skill; variable learner engagement; limited skills training
Simulation-based learning (SBL)	Clinical skills; decision-making under pressure; team collaboration	High-risk or low-frequency scenarios (e.g., diabetic emergencies); procedural practice; interdisciplinary communication	Safe, repeatable practice; immediate feedback; realistic environment; enhances confidence	Resource-intensive; may not transfer directly to real patients; focuses on observable behaviors over underlying reasoning
Integrated PBL–SBL	Comprehensive clinical competence: cognitive + behavioral integration	Complex endocrine cases requiring both mechanistic understanding and practical management (e.g., chronic disease with acute exacerbation)	Synergistic reinforcement of reasoning and action; addresses limitations of each method alone; prepares learners for real-world complexity	Limited empirical evidence; high resource demand; complex curriculum design; more intensive faculty development

based (OSCE) outcomes, along with assessor blinding, represents a methodological strength compared to many studies in this field. The findings suggest that integrating PBL-based analysis and discussion with SBL-based scenario experience may support the synchronous development of theoretical knowledge and clinical skills, while also enhancing learners' sense of participation and intrinsic motivation. However, as a single-center study with a relatively small sample size and only immediate post-intervention assessment, these findings require replication in larger, multicenter contexts with longer-term follow-up to determine whether the observed skill advantages persist and translate into improved patient care.

Overall, existing research on the integrated application of PBL and SBL in endocrinology education, while still limited in quantity, suggests that this integrated approach may offer advantages over either method used alone. By linking problem analysis with situational experience and reflective feedback, integrated models can support the concurrent development of conceptual understanding and practical skills. In endocrinology, which requires both a strong grasp of complex physiological mechanisms and long-term clinical management competencies, this synergistic approach holds theoretical promise.

However, the evidence base supporting this promise remains preliminary. The limited number of studies formally evaluating integrated PBL–SBL models in endocrinology are all single-center interventions with small sample sizes and short follow-up periods. Whether their findings can be replicated across different institutions and learner populations is unknown. Moreover, consistent with the broader PBL and SBL literature, these studies share common methodological limitations: reliance on short-term outcomes such as learner satisfaction and confidence, predominance of non-randomized designs, insufficient detail in intervention reporting, and absence of patient-level outcomes. Collectively, these constraints weaken the strength of the conclusions that can be drawn about the true educational impact of integrated approaches.

Beyond questions of efficacy, translating integrated PBL–SBL models into routine hospital-based training faces substantial practical hurdles. One of them is considerable resource requirements. Particularly, PBL demands small groups and trained facilitators, while SBL requires simulation equipment, dedicated space, and technical support. Combining both approaches amplifies these demands, raising feasibility concerns for programs operating under real-world fiscal and staffing constraints. Faculty development is another critical prerequisite—many clinical educators lack training in PBL facilitation or simulation debriefing—yet the time and cost required for such training are rarely accounted for in implementation plans. Curricular integration remains structurally challenging as well, since residency schedules organized around clinical service often provide limited protected time for small-group learning and simulation-based sessions. Finally, the cost-effectiveness of integrated approaches has not yet been demonstrated; without evidence that the additional resource investment translates to measurably better educational or patient outcomes, securing institutional support for widespread adoption will remain difficult.

Future research should therefore advance on multiple fronts. Methodologically, the field needs multicenter studies with rigorous designs, validated outcome measures that extend beyond the immediate learning environment, and transparent reporting that enables replication. Developing comprehensive evaluation tools that can simultaneously assess cognitive decision-making and practical behavior will be essential. At the same time, implementation science approaches are needed to understand how integrated PBL–SBL models can be adapted to diverse training contexts, what resources are truly required, and whether their benefits justify the associated costs in routine hospital-based education. Addressing both the evidence gaps and the practical challenges will be necessary to translate this educational innovation from theoretical promise into sustainable practice. Table 1 provides a comparative overview of traditional teaching, PBL, SBL, and integrated PBL–SBL models in endocrinology education, summarizing their respective learning objectives, applicable scenarios, as well as advantages and limitations. This comparison highlights the distinctive characteristics of each approach and underscores the potential value of their synergistic integration.

5. Conclusion

Both PBL and SBL offer valuable approaches for optimizing clinical endocrinology education, with additional benefits such as improved learner satisfaction, knowledge acquisition, and self-reported confidence. The potential synergy between PBL and SBL is theoretically compelling, particularly for a discipline like endocrinology that requires integration of mechanistic understanding with long-term clinical management. However, the current evidence base remains preliminary: most studies are single-center interventions with short follow-up, rely heavily on subjective or short-term outcomes, and lack patient-level data. Additionally, the feasibility of implementing integrated approaches in routine hospital-based training—including resource requirements, faculty development needs, and cost-effectiveness—remains largely unexplored. Future research should prioritize multicenter studies employing validated, competency-based outcome measures and should evaluate not only efficacy but also the practical conditions under which these methods can be effectively implemented in real-world educational settings.

Key Points

• The inherent complexity of endocrinology, characterized by multi-system feedback loops and long-term disease management, poses significant challenges for traditional teaching methods in cultivating essential clinical reasoning and decision-making skills.

• Problem-based learning (PBL) promotes active, self-directed learning anchored in authentic clinical problems, thereby enhancing learners' understanding of disease mechanisms and diagnostic reasoning.

• Simulation-based learning (SBL) provides a safe, controlled environment in which learners can repeatedly practice clinical skills, manage high-risk scenarios, and develop teamwork competencies without compromising patient safety.

• While both PBL and SBL independently demonstrate positive educational outcomes, each has inherent limitations that can be mitigated through their synergistic integration.

• The combined application of PBL and SBL creates a powerful conceptual framework that links cognitive analysis with experiential practice through a structured three-stage process, holding significant promise for advancing competency-based education in endocrinology.

Availability of Data and Materials

Not applicable.

Author Contributions

All elements of the study and subsequent write-up were carried out by the author [YMY]. The author read and approved the final manuscript. The author has participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflicts of Interest

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