

The Development of a Peer-Assisted Learning Process Integrated with AI-Driven Learning in Endocrine Physiology to Enhance Analytical Thinking Skills among Preclinical Medical Students

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Abstract

This study aimed to: 1) develop a peer-assisted learning process integrated with AI-driven learning in endocrine physiology to enhance analytical thinking skills among preclinical medical students; 2) examine the effects of the developed learning process on students' analytical thinking skills by comparing pretest and posttest scores; and 3) evaluate students' satisfaction with the developed learning process. The sample consisted of 17 second-year preclinical medical students enrolled in the first semester at the Faculty of Medicine, Bangkokthonburi University, selected through purposive sampling. The study employed a research and development design combined with a one-group pretest-posttest design. The research instruments included the developed learning process, expert evaluation forms for appropriateness and quality, an academic achievement test, an analytical thinking skills test, and a satisfaction questionnaire. Data were analyzed using mean, standard deviation, the Index of Item-Objective Congruence, and a dependent samples t-test. The findings revealed that the developed learning process consisted of 11 systematic steps and showed a high level of appropriateness (IOC = 0.94) and the highest level of overall quality (M = 4.75, SD = 0.44). Students' posttest academic achievement and analytical thinking scores were significantly higher than their pretest scores at the .001 level. Their overall satisfaction with the learning process was also at the highest level (M = 4.74, SD = 0.44). These findings indicate that integrating peer-assisted learning with AI-driven learning can effectively support endocrine physiology learning and enhance analytical thinking skills among preclinical medical students.

Keywords: peer-assisted learning, AI-driven learning, endocrine physiology, analytical thinking skills, preclinical medical students

1. Introduction

Medical education in the twenty-first century is undergoing a profound transformation from a knowledge-transmission paradigm toward a digitally mediated learning ecosystem that prepares learners to think, analyze, use data, and make reasoned decisions within increasingly complex healthcare systems. Future physicians are expected not only to possess accurate biomedical knowledge but also to demonstrate digital competence, ethical awareness in the use of artificial intelligence (AI), an understanding of the limitations of information, and a strong sense of responsibility toward human life. Therefore, medical education in the AI era should not merely aim to produce students who “know more,” but should cultivate learners who can “think more deeply, analyze more systematically, and use technology with informed judgment.”

This direction is consistent with the global standards for basic medical education proposed by the World Federation for Medical Education, which emphasize that learning outcomes should encompass knowledge, skills, behaviors, values, and professional readiness. These outcomes should serve as the foundation for curriculum design, learning management, and learner assessment (World Federation for Medical Education [WFME], 2020, pp. 13–15). From the perspective of digital technology for education, this principle suggests that developing medical students requires more than completing prescribed content coverage. It requires a systematic learning design that aligns learning outcomes, instructional activities, digital media, interaction, feedback, and assessment in order to support the development of competencies that can be transferred into professional medical practice.

At the global health policy level, the World Health Organization has emphasized that digital health should be used to improve the quality, efficiency, equity, and sustainability of health systems (World Health Organization [WHO], 2021, pp. 8–10). This policy direction is directly relevant to medical education in Thailand because future physicians will work in healthcare environments increasingly shaped by large-scale health data, clinical decision-support systems, digital platforms, and AI-based tools. Consequently, Thai medical education must develop learners who possess biomedical competence, digital competence, and analytical thinking skills strong enough to use technology as a tool for learning and decision support, rather than allowing technology to substitute for human reasoning.

The course MD 25604, Head and Correlative Organs of Special Senses and Endocrine System, offered by the Faculty of Medicine, Bangkokthonburi University, clearly reflects the need for digitally enhanced learning design. The course content is complex, interconnected, and requires integration across anatomy, physiology, pathophysiology, and medical reasoning. Students must be able to connect the structures of the head, the organs associated with special senses, mechanisms of perception, and the endocrine system with health-related outcomes in a

systematic way. Learning through memorization or passive lectures alone is therefore insufficient for developing systems understanding and analytical thinking skills, both of which are essential foundations for clinical learning.

Nevertheless, basic medical science courses often encounter several instructional limitations, including dense content, limited instructional time, specialized terminology, diverse student backgrounds, and insufficient opportunities for deep analytical practice in class. If learning management continues to rely primarily on lecture-based instruction, students may be able to remember content but may not be able to explain mechanisms, analyze relationships, or apply knowledge to medical situations with confidence. This challenge is central to digital technology for education, which does not simply focus on selecting modern tools, but on designing learning systems that reduce content complexity, increase interaction, provide timely feedback, and support learners in regulating their own learning with quality and evidence.

Artificial intelligence has significant potential to support medical learning, particularly through adaptive learning, intelligent tutoring, generative feedback, simulation-based learning, and learning analytics. Simoni et al. (2025) reported that AI has been used in undergraduate medical education in various roles, including tutoring, self-assessment, simulation, examination generation, assessment support, and learning analytics. However, their review also indicated that evidence regarding the effects of AI on ethics, empathy, critical thinking, and clinical reasoning remains limited. This gap suggests that research on AI in medical education should move beyond the question of whether AI can be used for teaching and instead ask how AI should be pedagogically designed to enhance the thinking processes of medical students.

This concern is supported by Li et al. (2026), who systematically reviewed the use of AI-generated content in medical education and found that AIGC can support learning, scenario generation, knowledge access, and higher-order thinking. However, when AI is used without sound instructional design or teacher supervision, it may lead learners to depend on ready-made answers, reduce cognitive effort, and affect academic integrity. Similarly, Izquierdo-Condoy et al. (2025) argued that generative AI can function as a tool for promoting critical thinking, but it may also threaten the cognitive autonomy of medical learners if students use AI without questioning or verifying the reasoning behind its responses. Therefore, AI in basic medical science courses should be designed as cognitive scaffolding that helps students think, verify, analyze, and reflect, rather than as an answer-generating system.

At the same time, peer-assisted learning (PAL) provides an important social dimension for medical education. Learning does not occur only between the learner and content; it also emerges through explanation, discussion, questioning, feedback, and collaborative reflection. Li et al. (2025) found that PAL was more effective than traditional teaching methods in medical education in terms of theoretical knowledge, practical skills, learner satisfaction, and student

acceptance. A key strength of PAL is that it requires learners to organize their own thinking clearly enough to explain ideas to peers. Explaining concepts to peers is therefore simultaneously a learning process, a self-assessment process, and a process for developing analytical thinking.

However, PAL alone may have limitations regarding content accuracy, consistency of feedback, and differences in learner ability within small groups. Conversely, AI used alone may lack trust, human communication, and the professional community dimension of learning. Integrating PAL with AI-driven learning is therefore valuable from the perspective of digital technology for education. PAL serves as a social learning architecture, while AI functions as an intelligent learning support system. When both components operate together, learners can explain concepts to peers, receive feedback from AI, verify answers, analyze situations, and reflect on their understanding in a systematic learning process.

Based on the synthesis of related concepts and research, the researcher developed an 11-step peer-assisted learning process integrated with AI-driven learning. The process includes: identifying learning objectives and content; presenting learning content; organizing student groups; conducting interactive learning activities; peer teaching; discussion and knowledge exchange; problem-solving and simulation-based activities; providing feedback through AI and peers; assessing learning outcomes; reflective thinking and lesson summarization; and monitoring learning behaviors. This process reflects a systematic digital learning design in which AI is used as cognitive scaffolding, peers serve as a collaborative learning mechanism, feedback functions as a learning improvement mechanism, and learning analytics supports continuous instructional development.

For these reasons, the present study on the development of a peer-assisted learning process integrated with AI-driven learning in MD 25604 for 17 second-year medical students is significant for medical education in Thailand. It offers a concrete model of digital learning innovation that connects medical education with educational technology. The study addresses the realities of Thai medical classrooms, where content is dense, instructional time is limited, and learner readiness varies. More importantly, it proposes a way to use AI not as a substitute for teachers or student thinking, but as a tool to enhance learning, feedback, analysis, and reflection within a process where peers remain an essential mechanism of collaborative learning.

Ultimately, this study is not merely an attempt to develop learning activities for a single course. It proposes an important conceptual direction for the future of Thai medical education: digital technology becomes truly valuable only when it is designed to develop physicians who possess knowledge, reasoning, judgment, collaboration, and responsibility toward human life. In an era when AI can generate answers rapidly, medical education must design learning

experiences that enable students to ask deeper questions, analyze more carefully, and use technology more responsibly.

2. Research Objectives

The objectives of this research were as follows:

1. To develop a peer-assisted learning process integrated with AI-driven learning in endocrine physiology to enhance analytical thinking skills among preclinical medical students.
2. To examine the effects of the peer-assisted learning process integrated with AI-driven learning in endocrine physiology on the development of analytical thinking skills among preclinical medical students by comparing their pretest and posttest scores.
3. To evaluate preclinical medical students' satisfaction with the peer-assisted learning process integrated with AI-driven learning in endocrine physiology for enhancing analytical thinking skills.

3. Research Methodology

This study employed a research and development design combined with a one-group pretest-posttest experimental design. The research was conducted in three phases corresponding to the research objectives. Phase 1 focused on developing a peer-assisted learning process integrated with AI-driven learning in endocrine physiology. Phase 2 examined the effects of the developed learning process on preclinical medical students' analytical thinking skills by comparing pretest and posttest scores. Phase 3 evaluated students' satisfaction with the developed learning process.

The target population consisted of preclinical medical students at the Faculty of Medicine, Bangkokthonburi University, who were enrolled in basic medical science courses. The sample consisted of 17 second-year preclinical medical students enrolled in the first semester in MD 25604: Head and Correlative Organs of Special Senses and Endocrine System. The participants were selected through purposive sampling because they were studying content related to endocrine physiology and were able to participate in the learning activities throughout the study period.

The research instruments consisted of five main instruments. The first instrument was the peer-assisted learning process integrated with AI-driven learning in endocrine physiology. The process consisted of 11 steps: 1) goal setting and content alignment, 2) content delivery, 3) learner grouping, 4) interactive learning activities, 5) peer teaching, 6) collaborative discussion, 7) problem-solving and simulation, 8) AI and peer feedback, 9) learning assessment, 10) reflection and debriefing, and 11) learning behavior tracking. The second instrument was an expert evaluation form for assessing the appropriateness of the learning process. The third instrument was an expert evaluation form for assessing the quality of the learning process. The fourth instrument was an analytical thinking skills test in endocrine physiology. The fifth instrument was a satisfaction questionnaire for preclinical medical students after participating in the developed learning process.

The construction and validation of the research instruments were conducted systematically. The researcher reviewed relevant concepts, theories, and studies related to peer-assisted learning, AI-driven learning, analytical thinking skills, and endocrine physiology. The learning process was then synthesized and designed for an eight-week implementation period consisting of four learning topics, with each topic taught over two weeks. The draft learning process and instruments were reviewed by three experts to examine content validity, appropriateness, clarity, feasibility, and alignment with the research objectives. The Index of

Item-Objective Congruence was used to determine the consistency of the instruments. Suggestions from the experts were used to revise the learning process and instruments before implementation.

The experimental procedure was conducted in sequence. First, the researcher explained the research objectives, learning activities, roles of students, peer-group responsibilities, AI-supported learning procedures, and participation conditions to the sample group. Second, students completed the pretest to measure their baseline analytical thinking skills in endocrine physiology. Third, the learning process was implemented for eight weeks through peer-assisted activities, AI-supported questioning, simulation-based problem solving, feedback from peers and AI, discussion, and reflection. Fourth, students completed the posttest after the intervention. Finally, students completed the satisfaction questionnaire regarding the developed learning process.

Data were analyzed according to the research objectives. The appropriateness of the learning process was analyzed using the Index of Item-Objective Congruence. The quality of the learning process and students' satisfaction were analyzed using mean and standard deviation. The analytical thinking skills scores before and after the intervention were compared using a dependent samples t-test. Qualitative comments from experts and students' reflective responses were analyzed through content analysis to support the interpretation of the quantitative findings.

4. Research Results

The research results are presented according to the three research objectives: 1) the development of the peer-assisted learning process integrated with AI-driven learning in endocrine physiology, 2) the effects of the developed learning process on students' academic achievement and analytical thinking skills, and 3) students' satisfaction with the developed learning process.

4.1 Results of Developing the Peer-Assisted Learning Process Integrated with AI-Driven Learning

The developed peer-assisted learning process integrated with AI-driven learning consisted of 11 steps: 1) goal setting and content alignment, 2) content delivery, 3) learner grouping, 4) interactive learning activities, 5) peer teaching, 6) collaborative discussion, 7) problem-solving and simulation, 8) AI and peer feedback, 9) learning assessment, 10) reflection and debriefing, and 11) learning behavior tracking. The appropriateness of the learning process was evaluated by three experts using the Index of Item-Objective Congruence (IOC), as shown in Table 1.

Table 1 Appropriateness of the Peer-Assisted Learning Process Integrated with AI-Driven Learning

No.	Learning Process Step	IOC	Interpretation
1	Goal setting and content alignment	1.00	Appropriate
2	Content delivery	1.00	Appropriate

3	Learner grouping	1.00	Appropriate
4	Interactive learning activities	1.00	Appropriate
5	Peer teaching	1.00	Appropriate
6	Collaborative discussion	1.00	Appropriate
7	Problem-solving and simulation	1.00	Appropriate
8	AI and peer feedback	1.00	Appropriate
9	Learning assessment	1.00	Appropriate
10	Reflection and debriefing	0.67	Appropriate
11	Learning behavior tracking	0.67	Appropriate
Overall mean		0.94	Appropriate

As shown in Table 1, the overall appropriateness of the developed learning process was 0.94, indicating that the process was appropriate for implementation. Most steps received an IOC value of 1.00, while reflection and debriefing and learning behavior tracking received an IOC value of 0.67, which still met the acceptable criterion.

Table 2 Quality Evaluation of the Peer-Assisted Learning Process Integrated with AI-Driven Learning

No	Evaluation Item	M	SD	Interpretation
1	Clarity of learning objectives and outcomes	4.80	0.41	Highest
2	Appropriateness of the learning sequence	4.80	0.41	Highest
3	Alignment with endocrine physiology content	4.73	0.46	Highest
4	Appropriateness of peer-assisted learning activities	4.67	0.49	High
5	Appropriateness of AI-supported learning	4.73	0.46	Highest
6	Promotion of analytical thinking skills	4.87	0.35	Highest
7	Provision of learning feedback	4.67	0.49	High
8	Feasibility for implementation in a medical classroom	4.60	0.51	Highest

9	Design of learner participation activities	4.80	0.41	Highest
10	Overall quality of the learning process	4.80	0.41	Highest
Overall mean		4.75	0.44	Highest

As shown in Table 2, the overall quality of the developed learning process was rated at the highest level ($M = 4.75$, $SD = 0.44$). The highest-rated item was the promotion of analytical thinking skills ($M = 4.87$, $SD = 0.35$), indicating that the developed process was pedagogically appropriate and capable of supporting analytical thinking in endocrine physiology learning.

4.2 Effects of the Developed Learning Process on Students' Academic Achievement and Analytical Thinking Skills

The developed learning process was implemented with 17 second-year preclinical medical students enrolled in MD 25604: Head and Correlative Organs of Special Senses and Endocrine System at the Faculty of Medicine, Bangkokthonburi University. The intervention lasted eight weeks. The results of comparing students' academic achievement before and after the intervention are presented in Table 3.

Table 3 Comparison of Students' Academic Achievement Before and After the Intervention

Test	n	Full Score	M	SD	t	p
Pretest	17	30	16.12	2.62	12.36	< .001
Posttest	17	30	25.18	2.16		

As shown in Table 3, students' posttest academic achievement scores were significantly higher than their pretest scores at the .001 level. The pretest mean score was 16.12 ($SD = 2.62$), whereas the posttest mean score increased to 25.18 ($SD = 2.16$). This result indicates that the developed learning process enhanced students' academic achievement in endocrine physiology.

Table 4 Comparison of Students' Analytical Thinking Skills Before and After the Intervention

Test	n	Full Score	M	SD	t	p
Pretest	17	30	15.29	2.59	11.49	< .001
Posttest	17	30	24.06	2.28		

As shown in Table 4, students' posttest analytical thinking skills scores were significantly higher than their pretest scores at the .001 level. The pretest mean score was 15.29 (SD = 2.59), whereas the posttest mean score increased to 24.06 (SD = 2.28). These findings indicate that the peer-assisted learning process integrated with AI-driven learning effectively enhanced analytical thinking skills among preclinical medical students.

Table 5 Analytical Thinking Skills Classified by Component

Component of Analytical Thinking	Full Score	Pretest M	Pretest S.D.	Posttest M	Posttest S.D.	Change
Problem component identification	6	3.18	0.81	4.82	0.64	Increased
Explanation of data relationships	6	3.06	0.75	4.71	0.69	Increased
Physiological mechanism analysis	6	2.94	0.83	4.76	0.56	Increased
Causal reasoning	6	3.00	0.79	4.88	0.49	Increased
Logical conclusion	6	3.12	0.70	4.88	0.49	Increased
Total	30	15.29	2.59	24.06	2.28	Increased

As shown in Table 5, students' posttest scores were higher than their pretest scores in all components of analytical thinking. The highest posttest mean scores were found in causal reasoning and logical conclusion (M = 4.88, SD = 0.49), followed by problem component identification (M = 4.82, SD = 0.64), physiological mechanism analysis (M = 4.76, SD = 0.56), and explanation of data relationships (M = 4.71, SD = 0.69). These findings suggest that the developed learning process particularly supported students' ability to connect physiological mechanisms, analyze cause-and-effect relationships, and construct logical conclusions based on endocrine physiology knowledge.

4.3 Students' Satisfaction with the Developed Learning Process

After completing the eight-week learning activities, students completed a satisfaction questionnaire regarding the peer-assisted learning process integrated with AI-driven learning. The results are presented in Table 6.

Table 6 Students' Satisfaction with the Peer-Assisted Learning Process Integrated with AI-Driven Learning

No.	Satisfaction Item	M	S.D.	Interpretation
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1	The learning activities were clear and systematically organized.	4.65	0.49	Highest
2	The activities helped students better understand endocrine physiology.	4.76	0.44	Highest
3	Peer-assisted learning encouraged explanation and discussion.	4.71	0.47	Highest
4	AI helped generate questions and stimulate analytical thinking.	4.82	0.39	Highest
5	Feedback from peers and AI helped improve understanding.	4.71	0.47	Highest
6	Simulation-based activities helped connect knowledge with medical reasoning.	4.76	0.44	Highest
7	The learning process supported the development of analytical thinking skills.	4.82	0.39	Highest
8	Reflection after learning helped students identify strengths and areas for improvement.	4.59	0.51	Highest
9	The use of AI was appropriate for the level of medical students.	4.65	0.49	Highest
10	Overall satisfaction with the developed learning process	4.88	0.33	Highest
Overall mean		4.74	0.44	Highest

As shown in Table 6, students' overall satisfaction with the developed learning process was at the highest level ($M = 4.74$, $SD = 0.44$). The highest-rated item was overall satisfaction with the developed learning process ($M = 4.88$, $SD = 0.33$). This was followed by the use of AI to generate questions and stimulate analytical thinking and the learning process supporting analytical thinking skills ($M = 4.82$, $SD = 0.39$). These findings indicate that students perceived the integration of peer-assisted learning and AI-driven learning as engaging, supportive, and beneficial for understanding endocrine physiology and developing analytical thinking skills.

5. Discussion

The findings of this study are discussed according to the three research objectives: the development of the learning process, its effects on students' academic achievement and analytical thinking skills, and students' satisfaction with the developed process.

First, the peer-assisted learning process integrated with AI-driven learning in endocrine physiology was found to be appropriate and of high quality. The developed process consisted

of 11 systematic steps, including goal setting and content alignment, content delivery, learner grouping, interactive learning activities, peer teaching, collaborative discussion, problem-solving and simulation, AI and peer feedback, learning assessment, reflection and debriefing, and learning behavior tracking. The overall IOC value of 0.94 and the overall quality rating at the highest level ($M = 4.75$, $SD = 0.44$) indicate that the process was pedagogically sound and suitable for use in a preclinical medical education context.

This result may be explained by the systematic integration of peer-assisted learning and AI-driven learning. Peer-assisted learning provided a social learning structure in which students explained concepts, exchanged ideas, and verified their understanding with peers, while AI served as an intelligent learning support system for generating questions, providing feedback, stimulating reasoning, and supporting reflection. This aligns with the direction of outcome-based medical education, which emphasizes the development of knowledge, skills, values, and professional readiness (World Federation for Medical Education [WFME], 2020, pp. 13–15). Thus, the developed process was not merely a sequence of classroom activities but a structured instructional design that connected learning outcomes, interaction, feedback, assessment, and learner development.

The finding is also consistent with the current direction of AI use in undergraduate medical education. Simoni et al. (2025) reported that AI has been increasingly applied in medical education for tutoring, self-assessment, simulation, examination generation, assessment support, and learning analytics. However, evidence regarding the effects of AI on ethics, empathy, critical thinking, and clinical reasoning remains limited. The present study contributes to this gap by designing AI not as a replacement for teachers or learners' reasoning, but as cognitive scaffolding embedded within a peer-supported learning environment.

Second, students' academic achievement and analytical thinking skills after learning were significantly higher than before learning at the .001 level. This indicates that the developed process supported both content understanding and higher-order thinking in endocrine physiology. This subject requires students to understand hormones, endocrine glands, target organs, feedback mechanisms, and physiological regulation. Such content cannot be mastered through memorization alone; students must analyze relationships, explain mechanisms, connect cause and effect, and construct reasoned conclusions.

The improvement may have resulted from active engagement through peer teaching, group discussion, simulation-based problem-solving, AI-supported feedback, and reflection. Peer teaching required students to organize knowledge clearly enough to explain it to others, while discussion helped clarify misconceptions and construct shared understanding. Simulation-based activities encouraged the application of endocrine physiology concepts to meaningful medical situations, and AI-supported feedback helped students refine their

reasoning. These activities shifted students from passive receivers of information to active constructors of medical knowledge.

This finding is consistent with Li, Wang, and Wu (2025), who found that peer-assisted learning was more effective than traditional teaching methods in medical education in terms of theoretical knowledge, practical skills, learner satisfaction, and student acceptance. In this study, peer-assisted learning strengthened analytical thinking because students had to explain endocrine mechanisms, defend their reasoning, listen to alternative explanations, and revise their understanding through peer interaction. The results also align with Li et al. (2026), who indicated that AI-generated content can support medical students' learning, scenario construction, access to knowledge, and higher-order thinking when used appropriately.

Similarly, Izquierdo-Condoy et al. (2025) argued that generative AI can enhance critical thinking when it promotes questioning, verification, and reflective reasoning, but it may undermine cognitive autonomy if learners depend on AI without critical evaluation. The present study addressed this concern by positioning AI as a learning support tool under peer-assisted learning and teacher-guided activities. Therefore, AI was used to support reasoning rather than replace it.

The component-level results further support this interpretation. Students' posttest scores increased across all components of analytical thinking, particularly causal reasoning and logical conclusion. This suggests that the learning process helped students move beyond recalling endocrine physiology content toward connecting physiological mechanisms with cause-and-effect relationships. Such development is important in preclinical medical education because analytical thinking in basic medical science provides the foundation for future clinical reasoning.

Third, students' satisfaction with the developed learning process was at the highest level ($M = 4.74$, $SD = 0.44$). This indicates that preclinical medical students perceived the integration of peer-assisted learning and AI-driven learning as meaningful, engaging, and beneficial. The highest-rated item was overall satisfaction with the developed process, followed by the use of AI to generate questions and stimulate analytical thinking, and the perception that the process supported analytical thinking skills.

This high satisfaction may be explained by the active and interactive nature of the learning process. Students were not limited to receiving knowledge through lectures; they participated in explaining, questioning, analyzing, evaluating, and reflecting. AI increased the flexibility and responsiveness of learning by providing prompts, feedback, and learning support, while peer discussion and teacher guidance maintained the human-centered nature of the learning environment.

This result aligns with Li, Wang, and Wu (2025), who reported that peer-assisted learning positively influenced learner satisfaction and acceptance in medical education. It also corresponds with Simoni et al. (2025), who noted the potential of AI to support more personalized and interactive learning. Nevertheless, as Izquierdo-Condoy et al. (2025) emphasized, the use of generative AI in medical education must be carefully designed to prevent excessive dependence and preserve learners' cognitive autonomy. Therefore, the satisfaction results should not be interpreted as evidence that AI alone is sufficient, but rather that students valued AI when it was integrated into a structured, peer-supported, and pedagogically guided learning process.

Overall, the findings suggest that a peer-assisted learning process integrated with AI-driven learning can serve as an effective digital learning innovation for preclinical medical education. The process was appropriate, high in quality, effective in improving academic achievement and analytical thinking skills, and highly accepted by students. Its key contribution lies in balancing human collaboration with intelligent technology. Peer-assisted learning strengthened explanation, discussion, and shared understanding, while AI supported questioning, feedback, simulation, and reflection. This combination is particularly valuable for endocrine physiology, where students must analyze complex mechanisms and develop reasoning skills that support later clinical learning.

For Thai medical education, this study offers a practical approach for basic medical science courses that are content-dense, time-limited, and cognitively demanding. Rather than using AI merely as a technological trend, medical educators should design AI-supported learning environments that promote analytical thinking, feedback, ethical use, and learner autonomy. In this sense, the developed learning process provides a promising model for using digital technology in medical education while preserving the essential human dimensions of learning, collaboration, and professional responsibility.

Knowledge Derived from the Study

The knowledge derived from this study is the development of an integrated learning process that combines the strengths of peer-assisted learning and AI-driven learning to support endocrine physiology learning among preclinical medical students. The process emphasizes the use of AI as an intelligent learning support system and peer-assisted learning as a collaborative learning mechanism. AI supports content preparation, adaptive questioning, feedback, simulation, assessment, reflection, and learning behavior tracking, whereas peer-assisted learning promotes explanation, discussion, collaborative reasoning, peer feedback, and reflective learning. The overall structure of the learning process is presented in Figure 1.

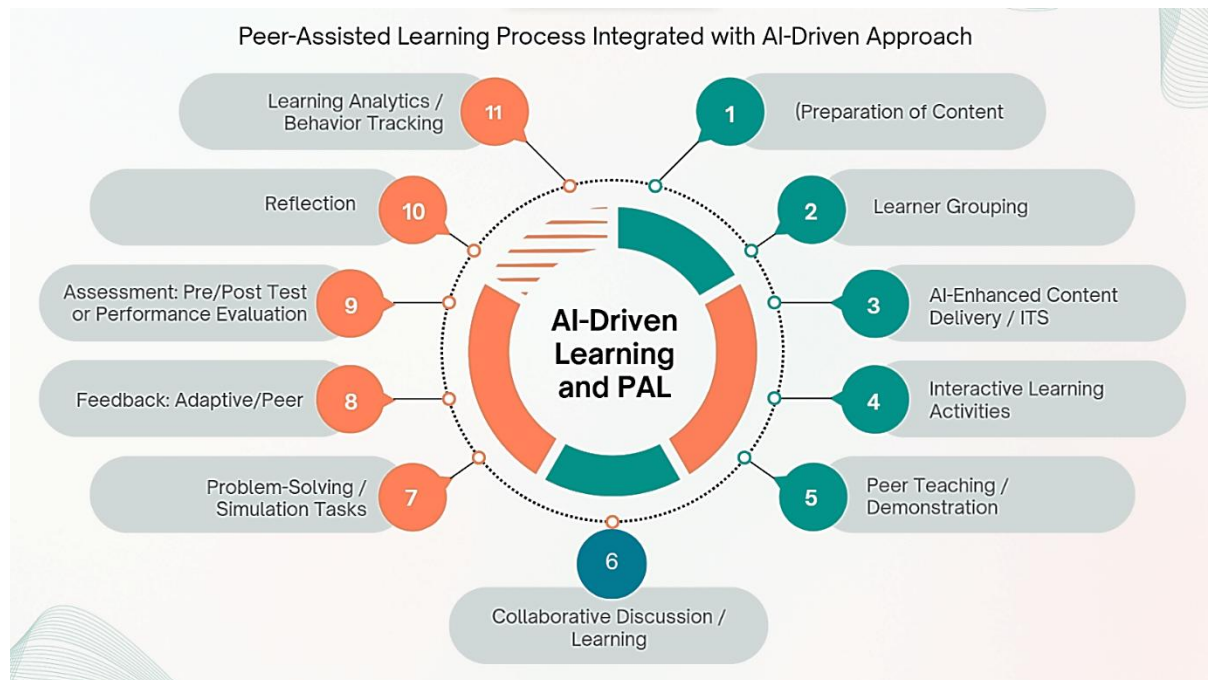


Figure 1. The Peer-Assisted Learning Process Integrated with AI-Driven Learning

Figure 1 should be placed immediately after the introductory paragraph above and before Table 1. This position allows readers to understand the overall structure of the 11-step learning process before examining the detailed components in the table. The figure functions as a conceptual overview, while the table provides an analytical explanation of the role of AI, the role of peer-assisted learning, and the learning outcomes expected from each step.

Table 7 Knowledge Derived from the Peer-Assisted Learning Process Integrated with AI-Driven Learning

Step	Learning Process Component	Role of AI-Driven Learning	Role of Peer-Assisted Learning	Knowledge Derived / Learning Outcome
1	Preparation of Content	Supports content organization, summary generation, question preparation, and adjustment of content difficulty according to learner readiness.	Students study prepared materials and build shared foundational understanding before class activities.	Students enter the learning process with more comparable prior knowledge and readiness for analytical learning.



2	Learner Grouping	Assists in analyzing pre-learning data or initial learning profiles to support appropriate grouping.	Students work in small groups with assigned roles such as explainer, questioner, and summarizer.	Collaborative learning begins through structured roles and reduced differences in learning readiness.
3	AI-Enhanced Content Delivery / ITS	Functions as a virtual tutor by explaining, expanding, and adapting content to individual learning needs.	Students discuss and clarify their understanding of AI-supported content with peers.	Complex endocrine physiology concepts become more accessible and systematically understood.
4	Interactive Learning Activities	Generates guiding questions, simulation prompts, and Socratic questions to stimulate reasoning.	Students interact with content, peers, and AI through questioning, explanation, and discussion.	Students develop active engagement and begin practicing medical reasoning.
5	Peer Teaching / Demonstration	Helps verify explanations, generate concept maps, and provide supportive prompts for peer teaching.	Students take turns explaining physiological mechanisms or concepts to peers.	Students organize their knowledge more clearly and improve academic explanation skills.
6	Collaborative Discussion / Learning	Provides open-ended questions, counterarguments, and summaries of discussion points.	Students exchange ideas, compare reasoning, and examine different interpretations.	Students strengthen analytical thinking through argumentation, comparison, and shared understanding.
7	Problem-Solving /	Creates clinical or physiological scenarios,	Students collaboratively	Students connect endocrine

	Simulation Tasks	modifies conditions, and checks the logical consistency of responses.	analyze problems and propose solutions.	physiology knowledge with medical situations and causal reasoning.
8	Feedback: Adaptive and Peer	Provides immediate, personalized, and criterion-based feedback.	Students provide peer feedback based on rubrics and group discussion.	Students identify strengths and weaknesses and continuously improve their understanding.
9	Learning Assessment	Supports the creation of adaptive quizzes, scenario-based questions, and analysis of learner weaknesses.	Students compare individual and group progress through pretest and posttest activities.	Students recognize their learning development and areas requiring improvement.
10	Reflection and Debriefing	Generates reflective prompts, summarizes key issues, and analyzes patterns in students' reflections.	Students reflect individually and collaboratively on their learning experiences.	Students develop metacognition and self-regulated learning.
11	Learning Analytics / Behavior Tracking	Tracks learning behaviors, participation, task completion, and learning progress through data analytics.	Students use learning data to reflect on and adjust their learning strategies.	Teachers and students gain evidence-based information for continuous learning improvement.

The key knowledge contribution of this study is that AI should not be used as a substitute for teachers or learners' thinking. Instead, AI should function as a precise, adaptive, and data-informed learning support system. At the same time, peer-assisted learning preserves the human dimension of medical education through explanation, dialogue, collaboration, peer feedback, and reflection. When both components are systematically integrated, the learning process can support both individual precision learning and collaborative learning.

In summary, the knowledge derived from this study can be conceptualized as follows: AI enhances precision, personalization, adaptive feedback, simulation, and learning analytics, while peer-assisted learning enhances explanation, collaborative reasoning, peer support, and reflective thinking. The integration of these two mechanisms creates a learning process that supports endocrine physiology understanding and develops analytical thinking skills among preclinical medical students. This model can be applied to other basic medical science courses that contain complex physiological mechanisms and require students to develop systematic reasoning before entering clinical learning.

6. Recommendations

Recommendations for Applying the Research Findings

1. Instructors in basic medical science courses should apply the peer-assisted learning process integrated with AI-driven learning to complex topics that require systematic conceptual connections, such as physiology, anatomy, pathophysiology, and other body systems. Learning activities should encourage students to explain, analyze, discuss, and reflect continuously.
2. The use of AI in medical education should be guided by a clear instructional framework. AI should be used to support questioning, feedback, simulation, and reasoning verification, rather than serving as a source of ready-made answers or replacing students' own thinking.
3. Students and instructors should be prepared before implementing the learning process, particularly in terms of peer roles, feedback methods, ethical AI use, and post-learning reflection. This preparation can help ensure effective implementation and maximize the development of analytical thinking skills.

Recommendations for Future Research

1. Future studies should examine the peer-assisted learning process integrated with AI-driven learning with a larger sample size or with a control group in order to strengthen empirical evidence and enhance the generalizability of the findings.
2. Future research should apply the developed learning process to other basic medical science courses, such as neuroscience, cardiovascular physiology, respiratory physiology, or metabolic systems, to examine its suitability across different medical content areas.
3. Future studies should investigate the effects of the learning process on other competencies of medical students, such as clinical reasoning, self-regulated learning, digital competence, ethical AI use, and collaborative learning skills, in order to expand knowledge on the use of digital technology in medical education.

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