

## Review Article

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# Artificial intelligence in medical problem-based learning: opportunities and challenges

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**Abstract:** Problem-based learning (PBL) in medical education has encountered challenges affecting both teachers and students. The integration of artificial intelligence (AI) into PBL may provide potential solutions to these challenges. This paper aims to discuss the potential advantages of AI, where we found these merits of AI have the potential to improve the quality of PBL lessons. It is also important to pay attention to ethical guidelines and other limitations of AI in PBL lessons as well. Examples of interactions with AI chatbots are provided to demonstrate its application possibility. It is recommended to try using AI in PBL lessons, making it more adaptable for the PBL classroom. Future research should further explore the capabilities of AI, with the goal of developing a more personalized and adaptive learning experience within PBL.

**Keywords:** artificial intelligence; problem-based learning; medical education

## Introduction

The problem-based learning (PBL) teaching paradigm is a student-centered educational approach that emphasizes self-directed problem-solving. This strategy encourages

students to engage with practical situations, facilitating their development in addressing real-world challenges. PBL involves a cognitive process where learners independently acquire and analyze knowledge, engage in group discussions, and make logical decisions. The primary objective of the PBL approach is to foster self-directed learning, critical thinking, collaborative skills, and the practical application of information. The participatory nature of this technique enhances teamwork and communication skills, making it particularly valuable in medical education [1].

Studies have demonstrated that PBL is an effective pedagogical approach, particularly in long-term knowledge retention and practical application. However, the effectiveness of PBL varies across different studies, and some limitations are noted [2]. These drawbacks can be categorized into three primary areas: teacher-related challenges, student-related issues, and administrative management-related problems. These include limitations in instructor expertise, the ability to thoroughly analyze complex scenarios, the capacity to propose innovative ideas, the influence in student's VARK (visual, aural, read/write, and kinesthetic), the anxiety about entitlement and self-actualization, constraints of interactive learning environment, and limitations within the evaluation system [3–6].

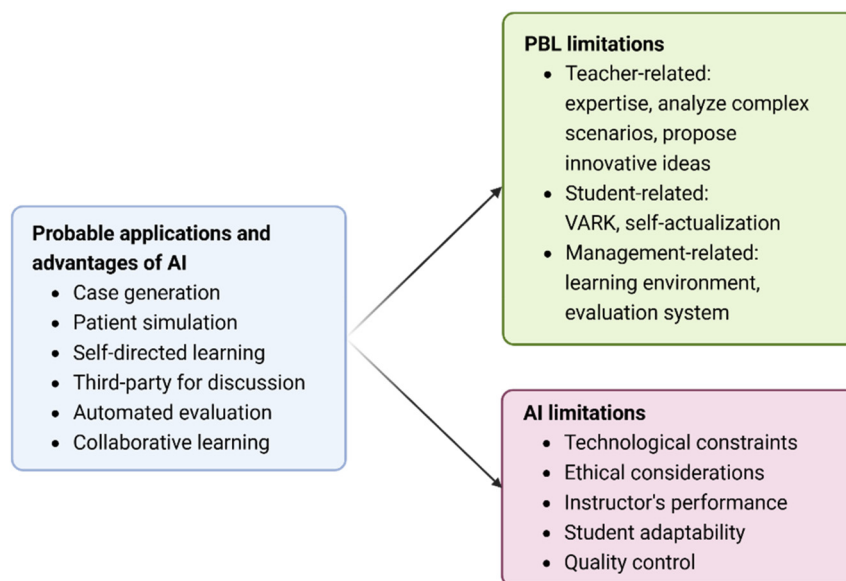
The rapid development of AI technology is revealing its growing potential for applications in the field of medical education. Integrating AI into medical education may exhibit several advantages, including objective student assessment, improved organization of simulations, and enhanced overall educational transparency. The general merits and demerits of AI in medical education are outlined in Table 1. AI has the potential to address various limitations inherent in PBL courses and to enhance the quality of PBL [7–9]. This paper will examine the possibilities of utilizing AI in PBL medical education courses. It will analyze the possible benefits of AI in overcoming the limitations of the PBL study process and highlight the problems and future advancements in this field (Figure 1).

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**Table 1:** Merits and demerits of AI in general medical education [7, 10–12].

| Merits                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Demerits                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
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| <ul style="list-style-type: none"> <li>–Enhanced learning and teaching</li> <li>–Preparation for future practice</li> <li>–Efficient curriculum design and evaluation</li> <li>–Innovative educational methods and learning experiences</li> <li>–Efficient handling of large datasets</li> <li>–Accessibility of learning resources</li> <li>–Virtual simulation and training</li> <li>–Diagnosis and treatment assistance</li> <li>–Objective assessment</li> <li>–Rapid feedback on performance to save time and effort</li> <li>–Potential as an adjunct tool</li> </ul> | <ul style="list-style-type: none"> <li>–Quality control issues</li> <li>–Ethical concerns</li> <li>–Impact on learning theories</li> <li>–Professional identity challenges</li> <li>–Infrastructure and technological challenges</li> <li>–Negative impact on feedback quality</li> <li>–Increased cheating and plagiarism potential</li> <li>–Lack of human touch and educational strategies</li> <li>–Over-reliance and skill neglect</li> <li>–Accuracy and bias issues</li> <li>–Current limited question types</li> </ul> |

**Figure 1:** The advantages and challenges of the application of artificial intelligence (AI) in medical problem-based learning (PBL) education. VARK, visual, aural, read/write, and kinesthetic.

## Probable applications and advantages of AI in PBL education

### Automated case generation

AI has the potential to automatically create individualized PBL scenarios, employing natural language processing and machine learning techniques. Especially, the numerous case reports and medical literature can be utilized to train AI. This application will speed up the case creation and enhance the diversity, taking into account specific learning objectives and the competency of individual students. Multimedia features generated by AI can also be integrated into teaching cases, such as photographs, videos, etc., which will enhance

the specificity and interaction [13]. Nevertheless, creating teaching cases places a heavy burden on teachers in terms of labor and time.

### Virtual patient simulation

AI-driven virtual patient technology offers students a more authentic and interactive clinical practice setting. This technology has the capability to replicate a wide range of behaviors and emotions, which allows students to improve their diagnostic and communication skills while boosting their abilities to provide compassionate care [14, 15]. The AI generated-patient may also boost their abilities to provide empathetic treatment.

## Promotion of self-directed learning

AI-powered systems can inspire students to actively participate in knowledge exploration. For instance, they could actively seek information about medical concepts and strive for solutions. AI can improve students' capacity for self-directed learning abilities and strengthen their critical thinking skills by providing prompt feedback and tailored recommendations [16]. The instant access to relevant information also saves students' time and effort, allowing them to focus more on the analysis of issues themselves. In addition, AI can generate learning materials and plans, as well as tailored feedback [17]. The comprehensive answers generated by AI could stimulate in-depth discussions and allow for the possibilities of diverse perspectives.

## Third-party for critical discussion

Since the introduction of chatbots, numerous studies found them more efficient and effective in providing relevant information than traditional information-searching methods [18].

Nevertheless, concerns over the accuracy, reliability, and presence of missing or incomplete data in generative AI are widely acknowledged [19]. AI still faces challenges in effectively and convincingly creating literature resources and generating consistent responses. Currently, there is a lack of comprehensive medical knowledge resource and a consensus-based metric for evaluating a resource's comprehensiveness. Medical textbooks, which are regarded as the gold standard in medical knowledge, may have limitations when it comes to PBL learning for training AI [20, 21]. The primary focus should be on teaching PBL learners to draw correct conclusions despite misleading, missing, or inaccurate data. Additionally, dealing with unusual disease presentations, unexplained lab results, and variations in information quality, whether from a consulting physician, textbook, or manuscript, presents challenges that resemble "black boxes" in clinical environments. Becoming comfortable navigating the uncertainties of AI technology in PBL discussion will probably benefit PBL learners as they encounter similar challenges in the clinical settings. Therefore, AI may work as the third-party for students and teachers to inspire critical thinking [17].

## Automated evaluation

Self-evaluation is one method for students to gain knowledge of their own strengths and weaknesses. AI may automatically provide evaluation reports by assessing students'

performance and comparing the solutions of all PBL participants in the learning process [22]. This analysis includes their engagement, the quality of their contributions, and their problem-solving skills. This function may offer solutions for teachers with unbiased evaluation standards and provides students with immediate feedback on their assignments [23]. The sentiment and visual analysis of students' responses, reactions, and levels of attentiveness with AI may be further utilized to predict their future outcomes. The information is helpful for identifying students who require further assistance, allowing teachers to provide targeted interventions [24, 25]. However, it should be noted that students may be reluctant to have machines evaluate human performance. It may be better to use AI in early warning mechanisms to judge objectively based on specific criteria.

## Improved collaborative learning

The group collaboration plays a pivotal role in PBL. Previous studies indicated that the use of AI technology could enhance participants' confidence and self-efficacy, fostering active involvement and engagement throughout the entire PBL process [18]. The introduction of chatbots into the PBL classes encouraged the asking of more questions during discussions and an atmosphere conducive to inquiry and exploration.

To summarize, the use of AI in PBL for medical education presents a multitude of possibilities to improve the learning process, deliver customized instruction, and equip future healthcare practitioners for a technologically sophisticated medical environment. Nevertheless, it is imperative to conscientiously incorporate new technologies, taking into account ethical considerations and upholding the human aspect in medical education.

## Potential limitations of AI in PBL studies

Currently, there is ongoing exploration of the use of AI in medical education. However, there are notable ethical obstacles that need to be addressed, including issues related to data collecting, ensuring anonymity, obtaining informed permission, and determining ownership of the data.

## Technological constraints

Despite notable advancements in AI technology, there are still limitations when it comes to understanding intricate

**Table 2:** Questions asked to Kimi.ai.**Students: What is metformin?****Kimi.ai:**

Metformin is an oral hypoglycemic agent used to treat type 2 diabetes. It controls blood glucose levels by reducing hepatic glucose production and enhancing the body's sensitivity to insulin. It is generally considered safe and is the first-line treatment for type 2 diabetes, as it helps prevent diabetes-related complications such as heart disease, stroke, kidney disease, and vision problems. However, recent studies have indicated that metformin may have negative effects on the elderly, potentially shortening their lifespan. Research from Fudan University has found that metformin may have adverse effects on older individuals, despite showing positive health effects in younger populations. This suggests that the use of metformin in the elderly should be approached with greater caution. Metformin also has potential side effects, including lactic acidosis, hypoglycemia, nausea, diarrhea, abdominal pain, indigestion, and fatigue. Patients using metformin may need to regularly monitor their blood levels of vitamin B<sub>12</sub>, as metformin can interfere with its absorption. Additionally, metformin may be beneficial for healthy aging, with some studies suggesting it could help delay the aging process. However, these findings do not imply that metformin can be used without restriction for anti-aging purposes, as the dosage and administration need to be adjusted based on individual circumstances and medical advice. Patients should follow their physician's guidance when using metformin and consult their doctor promptly if they experience any concerns or discomfort. Moreover, patients should avoid alcohol consumption while taking metformin, as it may increase the risk of lactic acidosis.

**Students: Can anyone with type 2 diabetes take it?****Kimi.ai:**

Not all patients with type 2 diabetes are suitable candidates for metformin use. Although it is the first-line medication for type 2 diabetes treatment, special caution or avoidance is required in the following situations:

**Renal impairment:** Metformin is excreted through the kidneys, and patients with impaired renal function may have an increased risk of lactic acidosis when using metformin. It is generally advised that patients with a glomerular filtration rate (GFR) less than 60 mL/min/1.73 m<sup>2</sup> should use metformin with caution or under medical supervision, and it is typically contraindicated in those with a GFR less than 30 mL/min/1.73 m<sup>2</sup>.

**Hepatic impairment:** Although metformin is not metabolized by the liver, its safety in patients with severe hepatic impairment remains controversial.

**Heart failure:** Patients with heart failure may have inadequate blood circulation, which can increase the risk of lactic acidosis.

**Alcohol abuse:** Alcohol can increase the risk of lactic acidosis, so metformin should be used with caution in individuals who abuse alcohol.

**Vitamin B<sub>12</sub> deficiency:** Long-term use of metformin may lead to vitamin B<sub>12</sub> deficiency, necessitating regular blood level monitoring and supplementation if needed.

**Acute illness:** During acute illness, such as infection or trauma, metformin should be temporarily discontinued, as the body may produce lactic acid, increasing the risk of lactic acidosis.

**Imaging procedures:** If undergoing imaging procedures with iodinated contrast agents, metformin should be temporarily discontinued to avoid increased risk of lactic acidosis due to contrast-induced renal effects.

**Surgery:** Metformin should be paused before and after surgery to prevent potential intraoperative and postoperative complications.

Before initiating metformin therapy, physicians will assess the patient's overall health status and determine the appropriateness and dosage adjustments based on renal function, liver function, cardiac status, and other health conditions. Patients should follow their physician's guidance and undergo regular necessary check-ups.

**Students: What other options are there?****Kimi.ai:**

For patients with type 2 diabetes who are not suitable candidates for metformin, several alternative treatment options are available:

**Insulin therapy:** Insulin is the primary treatment for type 1 diabetes but is also applicable to certain type 2 diabetes patients, particularly those who do not respond well to oral hypoglycemic agents or exhibit insulin resistance.

**Sulfonylureas (e.g., glibenclamide, gliclazide):** These medications stimulate the pancreatic beta cells to secrete more insulin.

**Meglitinides (e.g., repaglinide, nateglinide):** These drugs lower blood glucose by promoting rapid insulin secretion.

**Alpha-glucosidase inhibitors (e.g., acarbose):** These reduce postprandial blood glucose levels by slowing the absorption of carbohydrates in the intestines.

**Thiazolidinediones (e.g., pioglitazone):** These increase the body's sensitivity to insulin.

**DPP-4 inhibitors (e.g., sitagliptin, vildagliptin):** By inhibiting the DPP-4 enzyme, these medications increase GLP-1 levels, thereby stimulating insulin secretion and inhibiting glucagon release.

**SGLT2 inhibitors (e.g., dapagliflozin, empagliflozin):** These lower blood glucose by inhibiting renal glucose reabsorption, thereby increasing glucose excretion in the urine.

**GLP-1 receptor agonists (e.g., liraglutide, exenatide):** These mimic the action of glucagon-like peptide-1, stimulating insulin secretion, inhibiting glucagon release, and slowing gastric emptying.

**Lifestyle modifications:** Including dietary control and increased physical activity, which are foundational to the treatment of all type 2 diabetes patients.

**Bariatric surgery:** This may be an option for severely obese patients for whom other treatments have been ineffective.

Table 2: (continued)

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
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| <b>Students: What other options are there?</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <p>Comprehensive management of cardiovascular and renal diseases: This includes blood pressure control, lipid regulation, and antiplatelet therapy, among others.</p> <p>The choice of treatment should be based on the patient's specific circumstances and medical advice. Each medication has its own indications and potential side effects; therefore, it is important to thoroughly discuss any new treatment plan with a physician before initiation.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Students: What's the reasons of headache?</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <p><b>Kimi.ai:</b></p> <p>Headaches can be caused by a variety of factors, including:</p> <p>Tension: Stress or muscle tension can lead to tension headaches, which are the most common type of headache.</p> <p>Migraine: Migraines are severe headaches that can cause throbbing pain and sometimes be accompanied by nausea and sensitivity to light and sound.</p> <p>Cluster headaches: These are extremely painful headaches that occur in clusters or cycles.</p> <p>Dehydration: Not drinking enough water can lead to headaches.</p> <p>Caffeine withdrawal: Sudden reduction or cessation of caffeine intake can trigger headaches.</p> <p>Eye strain: Staring at screens for long periods can cause eye strain and headaches.</p> <p>Lack of sleep: Both oversleeping and undersleeping can lead to headaches.</p> <p>Dehydration: Not drinking enough fluids can cause dehydration, which can result in headaches.</p> <p>Hormonal changes: In women, hormonal fluctuations related to menstruation or menopause can cause headaches.</p> <p>Infections: Headaches can be a symptom of a cold, flu, sinus infection, or other infections.</p> <p>High blood pressure: Headaches can be a symptom of high blood pressure.</p> <p>Head injuries: Even minor head injuries can cause headaches.</p> <p>Substance use or overuse: Overuse of pain relievers can cause rebound headaches.</p> <p>Food allergies: Some people may experience headaches as a result of food allergies.</p> <p>Environmental factors: Exposure to loud noises, strong odors, or high altitudes can cause headaches.</p> <p>Medications: Certain medications can cause headaches as a side effect.</p> <p>Postural problems: Poor posture, especially when sitting at a desk or using a computer, can lead to tension headaches.</p> <p>Nutrient deficiencies: Lack of certain nutrients, like magnesium, can cause headaches.</p> <p>If you're experiencing headaches frequently or they are severe, it's important to consult a healthcare professional to determine the cause and appropriate treatment.</p> |

medical settings and interpreting natural language. AI's difficulty in interpreting complex medical scenarios is indeed a significant concern. AI may encounter challenges in accurately understanding and providing responses to open-ended and multiple logical inference questions asked by students in PBL conversations. As the field of medicine is highly intricate, involving a multitude of variables such as patient symptoms, medical history, test results, and treatment options, poses a considerable challenge for AI to accurately understand and analyze such complex settings. Furthermore, students may ask open-ended and multiple logical inference questions that require a deep understanding of the medical context. Current AI systems continue to face challenges when it comes to handling data that is unclear or lacks a defined structure.

One area for exploration could be the development of more advanced natural language processing techniques. By improving the ability of AI to understand and analyze natural language, it may be possible to enhance its performance in interpreting complex medical scenarios. For example,

incorporating techniques such as deep learning and neural networks could help AI better understand the nuances of medical language and improve its ability to answer complex questions. Another approach could be the integration of more comprehensive medical knowledge bases to train the AI chatbots. By providing AI with access to a vast repository of medical information, it may be able to draw on a wider range of knowledge to understand and analyze complex medical scenarios. This could involve the integration of electronic medical records, research papers, and clinical guidelines to provide a more comprehensive understanding of medical conditions.

### Ethical considerations

Integrating AI into medical education may lead to ethical considerations. AI algorithms trained on biased data can lead to incorrect diagnoses and unreasonable or unjust decisions. It is crucial to take into account the equity and clarity of AI decision-making in order to guarantee the precision of AI system assessments [26]. Further concerns include the

**Table 3:** Questions asked to different AI chatbots.**Question: What are the opioids? What are their mechanisms of action and side effects?****Kimi.ai:**

Opioids are a class of drugs that include natural alkaloids like morphine and codeine, which are derived from the opium poppy plant, as well as synthetic and semi-synthetic drugs like oxycodone, hydrocodone, and fentanyl. They are primarily used for pain relief and work by binding to opioid receptors in the brain and body, which are involved in the modulation of pain signals. Opioids can also produce a sense of euphoria, which is a significant factor in their potential for addiction.

The mechanisms of action of opioids involve binding to specific G protein-coupled receptors (mu, delta, kappa, and nociceptin), which are found in the brain, spinal cord, and other tissues. This binding activates a series of intracellular signaling pathways that inhibit the release of neurotransmitters involved in pain transmission, leading to analgesia. Opioids also affect other physiological systems, impacting respiration, gastrointestinal motility, the endocrine system, and the immune system.

Common side effects of opioid use include:

- Sedation and dizziness
- Nausea and vomiting (which often improve after the first few days of use)
- Constipation (which can be persistent and may require ongoing management)
- Respiratory depression, particularly a concern with higher doses or in new users
- Tolerance and dependence with prolonged use
- Potential for addiction

Less common but serious side effects can include:

- Delayed gastric emptying
- Hyperalgesia (increased sensitivity to pain)
- Immunologic and hormonal dysfunction
- Muscle rigidity and myoclonus

The misuse of opioids, especially when not prescribed or monitored by a healthcare professional, can lead to life-threatening situations such as overdose, which may result in death due to respiratory depression. It is crucial to use opioids under medical supervision and to be aware of the risks associated with their use. Opioids also have the potential to cause other issues such as sexual dysfunction, cognitive impairment, and allergic reactions in some individuals. When opioids are used over a long period, they can lead to hormonal imbalances that affect sexual function, contribute to cognitive issues like difficulty concentrating, and in rare cases, cause allergic reactions. In conclusion, while opioids are effective for managing moderate to severe pain, they need to be used with caution due to their potential side effects and the risk of dependence and addiction. Regular medical supervision is essential for safe opioid use.

**Doubao:**

Opioids are a class of drugs that are either derived from the opium poppy plant (such as morphine) or are synthetic substances that act on the opioid receptors in the body. They are commonly used for pain relief but also have a high potential for abuse.

Mechanisms of action

Opioids bind to specific opioid receptors in the central nervous system (CNS), peripheral nervous system, and other tissues. There are three main types of opioid receptors: Mu – opioid receptors (MOR), delta – opioid receptors (DOR), and kappa – opioid receptors (KOR). When opioids bind to mu – opioid receptors, which are the most relevant for their analgesic (pain – relieving) effects, they initiate a series of intracellular signaling events. This binding inhibits the release of neurotransmitters such as substance P, which is involved in transmitting pain signals. It also modulates the activity of neurons in the pain pathways, reducing the perception of pain.

In addition to pain relief, opioids can cause sedation, euphoria, and a decrease in the cough reflex. They also affect the control of respiration. The respiratory center in the brainstem is sensitive to opioids, and high doses can lead to respiratory depression, which is a major cause of opioid – related overdose deaths.

Side effects:Gastrointestinal effects

Nausea and vomiting are common side effects, especially when starting opioid treatment. This is due to the stimulation of the chemoreceptor trigger zone in the brain.

Constipation is another very common and often persistent side effect. Opioids slow down the movement of the gastrointestinal tract by affecting the enteric nervous system and smooth muscle function.

Central nervous system effects

In addition to the desired effects of pain relief and sedation, opioids can cause dizziness, confusion, and drowsiness. High doses or long – term use can lead to tolerance (requiring higher doses to achieve the same effect), dependence, and addiction.

As mentioned before, respiratory depression is a serious side effect, especially in cases of overdose.

Endocrine and immune system effects

Opioids can disrupt the normal function of the endocrine system. For example, they can affect the hypothalamic – pituitary – adrenal axis, leading to hormonal imbalances.

There is also evidence that opioids may have an impact on the immune system, potentially increasing the risk of infections in some cases.

Table 3: (continued)

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| <b>Question: What are the opioids? What are their mechanisms of action and side effects?</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>GPT-4o:</b> <p>Opioids are a class of drugs that are primarily used for pain relief. They work by binding to opioid receptors in the central nervous system, which include the brain and spinal cord. Opioids can be derived from the opium poppy (natural opioids like morphine and codeine), semi-synthetic (such as oxycodone and heroin), or fully synthetic (like fentanyl and methadone).</p> <p><u>Mechanisms of action</u></p> <p>Opioids exert their effects mainly through interaction with three types of opioid receptors: <math>\mu</math> (mu), <math>\kappa</math> (kappa), and <math>\delta</math> (delta). The primary actions include:</p> <p>Pain relief (analgesia): Opioids reduce the perception of pain by inhibiting the transmission of pain signals in the nervous system.</p> <p>Central nervous system depression: They dampen the excitability of neurons, leading to sedation and euphoria.</p> <p>Neurotransmitter release inhibition: Opioids inhibit the release of neurotransmitters by blocking calcium channels, thereby reducing the transmission of nerve signals.</p> <p><u>Side effects</u></p> <p>While effective, opioids come with a range of side effects, including:</p> <p>Respiratory depression: This is the most serious side effect, which can lead to decreased breathing or respiratory arrest.</p> <p>Constipation: A common issue due to reduced gastrointestinal motility.</p> <p>Nausea and vomiting: These occur due to stimulation of the brain's chemoreceptor trigger zone.</p> <p>Sedation and drowsiness: Opioids can cause significant central nervous system depression, leading to drowsiness.</p> <p>Addiction and dependence: Long-term use can lead to physical dependence and psychological addiction.</p> <p>Tolerance: Over time, higher doses may be needed to achieve the same level of pain relief.</p> <p>Due to their potent effects and potential for addiction, opioid use must be carefully monitored and managed under medical supervision.</p> |

insufficient protection of privacy and the security of data of PBL learners. Strict compliance with informed consent should also be essential when using patient data to train AI systems [27, 28]. When integrating AI into medical education, four main principles of biomedical ethics, including autonomy, justice, non-maleficence, and beneficence, must be taken into account [29]. To address these principles, reducing bias in AI training data can significantly improve medical decision-making. Bias in the data used to train AI algorithms can lead to ethical concerns. Therefore, it is essential to ensure that the algorithms be designed to detect and correct for biases in the data to ensure accurate and fair decisions made by the AI.

Evolution of the instructor’s role

Instructors should acquire knowledge themselves with AI systems and take on the role of supervising these tools when AI is implemented. It is essential to instruct students on how to use chatbots, including informing them of the limitations and advantages of AI, guiding them in identifying false information, and ensuring adherence to ethical and moral standards. These should be integral part of training for teachers [30, 31].

Student adaptability

There are significant differences in how students acquire and adapt to new technology. There is currently a lack

of dedicated courses specifically tailored to chatbots. Certain students may encounter difficulties in adjusting to AI-assisted learning techniques, particularly those who are accustomed to traditional in-person instruction. Students should be offered sufficient advice and assistance to facilitate their adaptation to these novel learning methods [32–34].

To summarize, the successful and appropriate application of AI in PBL medical education requires resolving the technological, ethical, and practical problems associated with it.

How to use AI in PBL learning

In this study, we first aim to pose several questions to Kimi.ai (Table 2), similar to those described previously [35], and then, we align additional questions with PBL lessons. We have also asked the same questions with different AI tools (Table 3).

Here are some examples of questions that might be posed in a PBL course. Compared to previously described research, the responses generated by different AI software may vary. Notably, all these AI systems strive to comprehensively address the respective questions. However, it is essential to evaluate and correct AI-generated answers for potential omissions or errors according to textbooks, clinical guidelines, and expert opinions. For example, the

explanations provided for the causes of headaches may not be exhaustive. In PBL lessons, students might think about primary and secondary headaches when dealing with headache-related issues. Then, they would consider the whole systems to ensure that no possible causes of headache are missed. It should be noted that certain inaccuracies could raise risks to medical education.

We have also tried to ask different AI chatbots the same question. All answers provided the overview of opioids, including their mechanisms of action, and common side effects. None of the answers seem to have major errors. For some students, the answers also discussed potential interactions with other drugs and any special considerations for different patient populations. Generally, AI can assist students in providing directions for answering questions in PBL lessons. However, as far as we know, there are no tools or standards to judge AI chatbots in multiple aspects, such as accuracy, comprehensiveness, and scientific validity. Therefore, it is imperative to carefully engage with and collaboratively assess the AI's responses. Furthermore, AI chatbots designed and trained for medical knowledge are undergoing further development [36]. It is appreciated that AI is continually improving and that such a discussion will only represent a snapshot for this time.

## Conclusions and perspective

We have been investigating the application of AI chatbots to evaluate their benefits and risks in medical education. This article merely begins to explore their potential capabilities in PBL lessons. In the future, AI holds the promise of introducing more possibilities to medical education. It will assist in developing a more personalized and adaptive learning experience by tailoring content and difficulty to meet the needs of both teachers and students, thereby providing each student with an optimal learning path. Additionally, AI will promote the integration of medical education with other subjects, helping to address previously unknown knowledge in the classroom. One potential area of exploration is the continuous improvement of AI-driven adaptive learning systems. As of now, these systems show promise in tailoring content and difficulty to meet the needs of both teachers and students, providing an optimal learning path for each individual. For instance, an AI adaptive learning system could detect when a student is feeling frustrated or overwhelmed and adjust the learning pace and difficulty accordingly. It could also recommend specific learning activities or resources that are known to be effective for students with similar emotional and cognitive profiles. By doing so, these systems could offer an even more personalized education

experience that truly caters to the unique needs of each learner in PBL lessons.

While we acknowledge the power of AI, it also has significant limitations. It is crucial to further understand the areas where AI may be subject to error and to enable it to recognize and correct these mistakes. By continuously engaging in dialogue with AI and documenting these interactions, we can develop a more comprehensive understanding of its capabilities. Furthermore, we are exploring the use of AI with students under ethical guidelines and informed consent, particularly in enhancing highly interactive courses such as PBL.

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**Informed consent:** Not applicable.

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**Use of Large Language Models, AI and Machine Learning Tools:** Kimi, Chat-GPT 4o, Doubao as object of study. These large language models and AI were not used for manuscript writing.

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