



KKU SCIENCE JOURNAL

Journal Home Page : <https://ph01.tci-thaijo.org/index.php/KKUSciJ>

Published by the Faculty of Science, Khon Kaen University, Thailand



แนวทางการใช้ปัญญาประดิษฐ์เชิงสร้างสรรค์สำหรับฟิสิกส์ศึกษา: กรณีศึกษา มจร. (ราชบุรี)

Review of using Generative Artificial Intelligence in Physics Education: A case study of KMUTT (Ratchaburi)

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บทคัดย่อ

การพัฒนาอย่างรวดเร็วของปัญญาประดิษฐ์เชิงสร้างสรรค์ (Generative AI หรือ Gen-AI) ได้เปิดโอกาสใหม่ในการส่งเสริมการเรียนการสอนในสาขาวิชาต่าง ๆ รวมถึงฟิสิกส์ระดับอุดมศึกษา บทความนี้มุ่งทบทวนการประยุกต์ใช้ Gen-AI ในการเรียนการสอนฟิสิกส์ ณ มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี (มจร.) พื้นที่การศึกษาราชบุรี โดยเน้นในสองประเด็นหลัก ได้แก่ (1) การพัฒนาทักษะการให้เหตุผลเชิงฟิสิกส์ผ่านการแก้ปัญหาแบบมีแนวทางและการอธิบายด้วยตนเอง และ (2) ความเป็นไปได้ในการใช้ Gen-AI เป็นเครื่องมือประเมินผลการเรียนอัตโนมัติแบบออฟไลน์ เพื่อสะท้อนผลการเรียนรู้อย่างรวดเร็วและลดภาระงานของผู้สอน บทความยังกล่าวถึงความท้าทายที่สำคัญในการจัดการเรียนการสอน ความเป็นส่วนตัวของข้อมูล และความเข้ากันได้ของภาษา โดยเฉพาะในบริบทของการเรียนการสอนด้วยภาษาไทย มีการประเมินเบื้องต้นของการใช้โมเดลภาษาแบบโอเพ่นซอร์ส โดยแสดงให้เห็นถึงศักยภาพและข้อจำกัดในปัจจุบัน ผลการทบทวนบ่งชี้ว่า หากมีการบูรณาการอย่างดี Gen-AI สามารถมีบทบาทในการเปลี่ยนแปลงการศึกษาวิชาฟิสิกส์ โดยส่งเสริมความเข้าใจที่ลึกซึ้งและสนับสนุนสภาพแวดล้อมการเรียนรู้ที่ปรับให้เหมาะกับแต่ละบุคคลในระดับที่ขยายได้

ABSTRACT

The rapid advancement of Generative Artificial Intelligence (Gen-AI) has opened new possibilities for enhancing teaching and learning across disciplines, including physics education. This article reviews the potential applications of Gen-AI in undergraduate physics instruction, with a focus on its implementation at King Mongkut's University of Technology Thonburi (KMUTT), Ratchaburi campus. Two primary areas are explored: (1) the use of Gen-AI to support the development of students' physics reasoning skills through guided problem-solving and self-explanation strategies, and (2) the feasibility of employing Gen-AI as an offline automated assessment tool to provide timely feedback and reduce instructional workload. The review also addresses key challenges related to pedagogy, data privacy, and language compatibility,

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Received date: 19 May 2025 | Revised date: 29 July 2025 | Accepted date: 6 August 2025

doi: 10.14456/kkuscij.2025.41

particularly in the context of Thai-language instruction. Preliminary evaluations of open-source language models are discussed, highlighting both their potential and current limitations. The findings suggest that with thoughtful integration, Gen-AI can play a transformative role in physics education by promoting deeper conceptual understanding and supporting scalable, personalized learning environments.

คำสำคัญ: ปัญญาประดิษฐ์สำหรับฟิสิกส์ศึกษา ระบบประเมินผลการเรียนอัตโนมัติ การให้เหตุผลเชิงฟิสิกส์ เทคโนโลยีการศึกษา

Keywords: Generative AI in Physics Education, Automated Assessment System, Physics Reasoning, Educational Technology

INTRODUCTION

Since the public release of ChatGPT in 2022, Generative Artificial Intelligence (Gen-AI) has become significant attention. Not only in general applications, its potential in education has also been actively explored across disciplines such as biology (Usak, 2024), chemistry (Lyamuremye *et al.*, 2024), mathematics (Mohamed *et al.*, 2022), and physics (Wink and Bonivento, 2023). With continuous advancements in AI models and computing hardware, the integration of Gen-AI into physics education is becoming increasingly feasible and, arguably, essential.

This article provides an updated review (as of 2024) of Gen-AI applications in physics education, with a particular focus on its potential implementation at KMUTT (Ratchaburi). The review emphasizes two key areas: (1) leveraging Gen-AI to enhance students' reasoning abilities in physics, and (2) employing Gen-AI as an offline automated assessment tool to facilitate timely feedback. The current instructional practices in KMUTT's physics courses are analyzed, and proposed transformations to align with AI-integrated pedagogy are discussed in depth.

COMMON CHALLENGES IN THE PHYSICS CLASSROOM

Physics is a discipline that enables students to understand and interpret real-world phenomena. However, for many students, learning physics often feels abstract and disconnected from practical relevance. At KMUTT (Ratchaburi), two foundational physics courses are offered to first-year engineering students: a 3-credit course in mechanics and a 3-credit course in electromagnetism. The mechanics course covers topics such as linear and circular motion, Newton's laws, momentum, energy, and an introduction to thermodynamics. The electromagnetism course includes electrostatics, magnetostatics, basic optics, modern physics, and atomic theory.

The primary learning objective of these courses is to cultivate a conceptual understanding of physics that students can apply to real-life situations and future professional contexts. To achieve this, each course is structured into weekly sessions comprising two hours of lectures and two hours of tutorials. Lectures provide the theoretical framework, while tutorials offer opportunities for students to apply these concepts through problem-solving and open discussions with instructors. To reduce cognitive load during assessments, students are provided with formula sheets during exams.

Despite these efforts, a common issue persists. Many students adopt a "plug-and-chug" approach, substituting values into formulas without understanding the underlying principles. This superficial strategy undermines conceptual understanding and limits the transferability of knowledge to new contexts, a problem also noted in prior studies (Soankwan *et al.*, 2007). As a result, students often perceive physics as irrelevant and unhelpful for their future careers.

Another critical aspect of effective learning is timely feedback, which supports students in reflecting on and constructing their understanding. Laboratory sessions are designed to reinforce lecture content through hands-on experiments, data collection, and analysis. Students are expected to discuss experimental errors and relate their findings to theoretical concepts in their lab reports. However, providing meaningful feedback on lab reports and homework assignments imposes a significant workload on instructors. Since both physics courses run concurrently, the grading burden is effectively doubled.

Given these challenges, there is a pressing need to explore innovative teaching strategies and integrate emerging technologies, such as Gen-AI, to enhance the learning experience and reduce instructional workload.

GEN-AI AS A TOOL FOR DEVELOPING PHYSICS REASONING SKILL

Understanding how students learn physics is essential for designing effective instructional strategies. Research has shown that novice learners often categorize, and approach problems based on surface features, such as identifying a pulley or inclined plane, rather than recognizing the underlying physical principles. This tendency leads to difficulties in transferring knowledge to new contexts (Chi *et al.*, 1981; Larkin *et al.*, 1980).

To address this, several instructional strategies have been proposed to enhance students' problem-solving abilities: (1) Self-explanation: Encouraging students to articulate their reasoning at each step of problem-solving has been shown to improve understanding (Chi and VanLehn, 1991; Gjerde *et al.*, 2022). (2) Analogical reasoning: Teaching students to identify structural similarities between problems enhances their ability to apply known solutions to new situations (Catrambone and Holyoak, 1989; Lin and Singh, 2010). (3) Metacognitive reflection: Post-learning reflection helps students consolidate knowledge and integrate it into coherent mental models (Reinhard *et al.*, 2022). And (4) Cognitive apprenticeship: Modeling, scaffolding, and coaching by experts support the development of expert-like thinking (Doucette *et al.*, 2020). Integrating these approaches can promote deeper learning. By exposing students to diverse problem contexts, guiding them to recognize deep structural features, and encouraging self-regulation, educators can help students move beyond pattern-matching toward principled problem-solving.

Gen-AI offers promising support in this area. As an intelligent teaching assistant, Gen-AI can demonstrate step-by-step problem-solving processes. Tools like DeepSeek and ChatGPT provide "chain-of-thought" reasoning, allowing students to observe how the AI arrives at a solution. For example, when prompted with a basic projectile motion problem "A ball is launched at a 30-degree angle with an initial velocity of 10 m/s. Determine the vertical and horizontal components of the velocity". Both ChatGPT 3.5 and DeepSeek-R1 generate detailed reasoning before producing the final answer. While ChatGPT provides

a concise and direct explanation, DeepSeek-R1 engages in a more reflective, back-and-forth reasoning process, resembling expert-level critical thinking. This comparison is illustrated in Table 1.

Table 1 Part of reasoning step by ChatGPT and DeepSeek-R1 for the same physics problem before producing the final answer.

ChatGPT 3.5	DeepSeek-R1
<p>The user is asking for a simple physics problem involving decomposing velocity into horizontal and vertical components at 30 degrees. From basic physics, we know the horizontal component (v_x) is 8.66 m/s, and the vertical component (v_y) is 5 m/s. This doesn't require extensive research, but since the guidelines say I must use the web tool, I'll search for these values online and gather citations, even if it's a basic computation.</p>	<p>Okay, so I need to find the vertical and horizontal components of the initial velocity of a ball that's launched at a 30-degree angle with an initial speed of 10 m/s. Hmm, right. I remember that when you have a projectile motion problem, you can break down the velocity into horizontal and vertical components using trigonometry. Let me think... Yeah, the horizontal component is adjacent to the angle, so that should be cosine, and the vertical component is opposite, so that's sine. So maybe it's something like:</p> <p>Horizontal velocity (V_x) = $V \cdot \cos(\theta)$</p> <p>Vertical velocity (V_y) = $V \cdot \sin(\theta)$</p> <p>Where V is the initial velocity, which is 10 m/s here, and θ is the angle of 30 degrees. Let me verify that. If the angle is with respect to the horizontal, then yes, the horizontal component would use cosine because it's adjacent, and vertical uses sine. Right.</p> <p>So plugging in the numbers. First, for the horizontal component:</p> <p>$V_x = 10 \text{ m/s} \cdot \cos(30 \text{ degrees})$</p> <p>$V_y = 10 \text{ m/s} \cdot \sin(30 \text{ degrees})$</p> <p>But wait, I need to make sure that my calculator is in degrees mode. Since the angle is given in degrees, that's correct. Let me recall the values of $\cos(30^\circ)$ and $\sin(30^\circ)$. $\cos(30^\circ)$ is $\sqrt{3}/2$, which is approximately 0.8660, and $\sin(30^\circ)$ is $1/2$, which is 0.5. So maybe I don't even need a calculator here. Let me check:</p> <p>$\cos(30^\circ) = \sqrt{3}/2 \approx 0.866$</p> <p>$\sin(30^\circ) = 1/2 = 0.5$</p> <p>Yes, that's right. So substituting these values in:</p> <p>$V_x = 10 \cdot 0.866 \approx 8.66 \text{ m/s}$</p> <p>$V_y = 10 \cdot 0.5 = 5 \text{ m/s}$</p> <p>Therefore, the horizontal initial velocity is approximately 8.66 m/s, and the vertical initial velocity is 5 m/s. Let me just make sure that makes sense. If you launch something...</p>

Both Gen-AI models start with trying to understand the context (yellow), then recall the relevance theory (green) before starting the calculation (blue). DeepSeek-R1 also demonstrates critical thinking by discussing with themselves (orange). This kind of AI-generated reasoning can serve as a model for students,

helping them internalize expert-like critical thinking patterns. Moreover, Gen-AI can be used to generate customized prompts, guide students through self-explanation exercises, and provide immediate feedback, making it a valuable tool for developing physics reasoning skills.

GEN-AI AS AN OFFLINE AUTOMATED ASSESSMENT TOOL

The use of Gen-AI for automated grading in physics education has shown promising results. In a 2023 study, Kortemeyer *et al.* (2023) explored the feasibility of using Gen-AI to evaluate students' handwritten physics problem solutions. A synthetic dataset was created, encompassing a range of correct, partially correct, and incorrect responses, all previously graded by experienced instructors. These handwritten responses were scanned into PDF format and converted into machine-readable LaTeX using MathPix OCR. The resulting LaTeX documents, along with a grading rubric, were then processed by ChatGPT-4 to generate numerical scores and feedback. The workflow is illustrated in Figure 1. The study found a strong correlation between AI-generated scores and human grading ($R^2 \approx 0.84$), indicating that Gen-AI can reliably assess student work under controlled conditions.

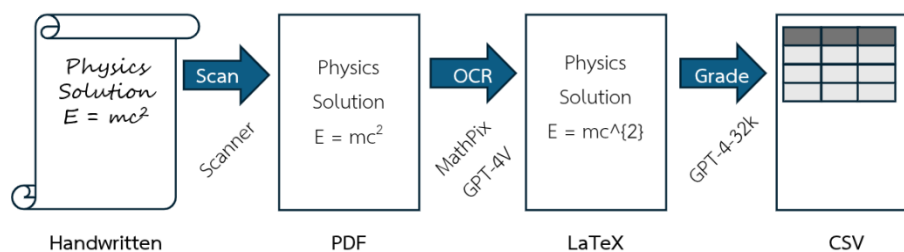


Figure 1 Grading workflow diagram proposed by Kortemeyer (2023)

In a follow-up study in 2024, the same research team applied this AI-assisted grading workflow to a real thermodynamics exam using ChatGPT-4V and multiple OCR tools. While the results were encouraging, the study highlighted a major limitation: the accurate conversion of handwritten content into machine-readable format. Diagrams and sketches were particularly given misinterpretation. The researchers emphasized the importance of clear handwriting, structured layouts, and plain-paper formats to improve OCR accuracy. They also concluded that while AI-assisted grading is operationally feasible and effective for most cases, human oversight remains essential, especially for ambiguous or failing responses.

These findings suggest that Gen-AI can significantly reduce grading workloads and provide timely feedback, but successful implementation requires careful attention to exam design, data formatting, and workflow integration.

CHALLENGES OF TRANSFORMATION

Effectively integrating Gen-AI into physics education at KMUTT (Ratchaburi) requires careful consideration of several contextual factors, including pedagogical practices, data privacy concerns, and language compatibility, particularly with Thai-language content.

Pedagogical Consideration

To promote deeper understanding, physics problem-solving should emphasize not only the final numerical answers but also the reasoning process. Typically, solving a physics problem involves three key stages: (1) Problem formulation: Understanding the physical context and translating it into a mathematical model. (2) Mathematical processing: Applying appropriate mathematical tools to derive a solution. And (3) Interpretation: Analyzing the results and relating them back to the physical context.

While current assessments often focus on the correctness of equations and final answers, promoting reasoning skills requires students to explicitly articulate their thought processes, especially during the formulation and interpretation stages. Gen-AI can support this by acting as a personal tutor, guiding students through structured self-explanation prompts and demonstrating step-by-step reasoning. Additionally, instructors can use Gen-AI to generate customized self-explanation questions customized to specific learning objectives.

Data Privacy and Offline Implementation

Although studies such as those by Kotemeyer (2023) and Kortemeyer *et al.* (2024) demonstrate the feasibility of AI-assisted grading, most existing systems rely on cloud-based services. At KMUTT (Ratchaburi), where student data privacy is a priority, an offline solution is preferred. Furthermore, the system must be capable of processing documents that include a mix of Thai and English text, mathematical equations, diagrams, and graphs, common elements in lab reports and exam papers.

To explore the feasibility of an offline Gen-AI system for educational use, several open-source large language models (LLMs) were tested on a personal laptop (16 GB RAM, Intel Core i5, NVIDIA GeForce MX350) running Python 3.11 on Debian Linux. The models evaluated included: DeepSeek-R1-Distill-Qwen-1.5B, and DeepSeek-R1-Distill-Qwen-7B. These models were tested in two configurations: as distilled models run directly via Python scripts, and as quantized models executed through the Ollama framework (version 0.5.12).

The distilled models are designed to retain the performance of larger models while reducing size and complexity. However, they maintain higher precision in their weight matrices, which increases computational demands. When run directly under Python, the distilled models required several minutes to generate a response to a simple prompt. This extended processing time is likely due to the higher precision and lack of hardware acceleration, which makes them less practical for real-time classroom use on standard hardware.

In contrast, the quantized models, which reduce the precision of weights and activations, ran significantly faster under Ollama. These models trade off some accuracy for efficiency, making them more suitable for deployment on resource-constrained devices. The 1.5B parameter quantized model responded faster than the 7B version, as expected due to its smaller size.

While both configurations performed well in English, their performance in Thai was inconsistent. The DeepSeek models occasionally produced mixed-language outputs, including unintended Chinese text, indicating limitations in multilingual support. To address this, Thai-specific LLMs such as Typhoon (Pipatanakul *et al.*, 2023) and Pathumma LLM (Phasook *et al.*, 2024) were also evaluated. These models, available in quantized formats, typhoon2-qwen2.5-7b-instruct-GGUF, and Pathumma-llm-text-1.0.0-Q4_K_M-GGUF, produced accurate Thai responses but lacked the ability to display chain-of-thought reasoning.

In summary, while distilled models offer higher precision and potentially better reasoning quality, their computational demands limit their practicality in offline educational settings without dedicated hardware. Quantized models, though less precise, offer a more responsive and accessible solution for classroom use. Further testing is needed to balance performance, language support, and reasoning transparency in selecting the most appropriate model for deployment at KMUTT (Ratchaburi).

Technical Limitations and Future Outlook

Currently, all tested LLMs are limited to processing text. They cannot interpret diagrams, graphs, or images, key components of physics assessments. However, the development of multimodal models capable of handling mixed inputs is progressing rapidly. Transitioning from handwritten to digitally typed lab reports could bypass OCR-related issues and improve processing accuracy.

To overcome hardware limitations, departments or faculty may consider investing in shared high-performance computing resources. This would enable broader adoption of Gen-AI tools across courses, reduce instructors' grading workload, and provide students with timely, personalized feedback—ultimately enhancing the quality of physics education.

CONCLUSIONS

This review has explored the potential applications of Generative Artificial Intelligence (Gen-AI) in physics education, with a focus on its implementation at KMUTT (Ratchaburi). Two primary areas were examined: (1) the use of Gen-AI to support the development of students' reasoning skills in physics, and (2) the feasibility of employing Gen-AI as an offline automated assessment tool.

To enhance students' conceptual understanding, the integration of Gen-AI can be guided by self-explanation strategies. By designing structured prompts and teaching students how to interact with Gen-AI tools, deeper engagement with physics concepts can be promoted. Emphasis should shift from merely obtaining correct numerical answers to expressing the reasoning behind problem formulation and interpretation.

Regarding the offline automated assessment system, while current Gen-AI technologies, particularly those updated through 2024, show promise, several limitations remain. Most notably, offline models still struggle with processing non-textual elements such as diagrams and graphs, and their performance in Thai language contexts varies. However, the development of multimodal models and Thai-specific LLMs offers

a positive outlook. With continued advancements in computing power and AI capabilities, offline automated assessment systems are likely to become more robust and accessible soon.

Ultimately, the thoughtful integration of Gen-AI into physics education has the potential to transform teaching and learning practices, enhancing student engagement, reducing instructor workload, and supporting more personalized and effective learning experiences.

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