



Utilizing AI for Physics Problem Solving: A Literature Review and ChatGPT Experience

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Abstract

The integration of artificial intelligence (AI) tools in physics education is gaining traction, driven by their potential to enhance learning experiences and outcomes. This study aims to investigate the use of AI tools, particularly ChatGPT, in solving physics problems and enhancing educational practices. Utilizing a systematic literature review following PRISMA guidelines, the research identifies current trends and practical applications of AI in physics education. The results indicate that AI tools effectively support lesson planning, introduce innovative teaching methodologies, and assist in solving complex physics problems, significantly enhancing problem-solving skills and personalized learning experiences. However, challenges such as inaccuracies in handling advanced content, the lack of useful visual aids, and the need for human intervention to ensure the completeness and accuracy of AI-generated content were noted. Personal experiences, supplemented by an interview with a thermodynamics lecturer, revealed that while ChatGPT can simplify complex concepts and improve comprehension, it could not replace the mentorship and nuanced feedback provided by human educators. The study concludes with recommendations for integrating AI tools into physics education, emphasizing the need for balanced integration with traditional teaching methods, improved AI literacy among educators and students, and future developments focusing on personalized learning and enhanced visualization capabilities. The findings demonstrate the transformative potential of AI in physics education and highlight the importance of addressing its limitations to maximize educational outcomes.

Keywords: Artificial intelligence; Physics problem-solving; ChatGPT; Literature review; Personal experience; Thermodynamics.

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INTRODUCTION

The integration of artificial intelligence (AI) tools into educational practices is increasingly prevalent, driven by the potential to enhance learning experiences and outcomes. In the context of physics education, AI tools would offer innovative solutions to complex educational challenges, enabling more personalized and effective learning strategies. The application of AI in problem-solving activities can support students in developing critical thinking and analytical skills, which are essential for mastering scientific concepts and methodologies. Recent advancements in AI have facilitated the creation of sophisticated educational technologies that can adapt to the individual needs of learners, providing real-time feedback and customized learning pathways.

The integration of AI tools in physics has shown significant promise in problem-solving applications. AI, particularly through machine learning, a subset of AI, has been increasingly utilized in various fields, including, mechanical physics,

solid-state materials science, condensed matter physics, and the others, as discussed later. These applications demonstrated the potential of AI to enhance problem-solving capabilities by leveraging algorithms that can analyze complex datasets and patterns to derive insights and predictions. Schmidt et al. (2019) highlighted the effectiveness of AI in solid-state materials science, where AI algorithms could predict material properties and behaviors with high accuracy, facilitating new material discovery and design. Similarly, in medical physics, Cui et al. (2020) explored AI applications in medical imaging and radiation therapy, showcasing AI's ability to improve diagnostic accuracy and treatment planning. Bedolla et al. (2021) also illustrated AI's role in condensed matter physics, where it aided in identifying phase transitions and understanding complex physical phenomena.

The integration of AI tools into physics problem-solving is a transformative approach that addresses several longstanding challenges in the field. Traditional methods in physics often rely on extensive theoretical computations and empirical experiments, which can be time-consuming and resource-intensive. AI offers a paradigm shift by providing tools that can process vast amounts of data quickly and accurately, thus accelerating the problem-solving process. Carrasquilla (2020) emphasized the importance of AI in uncovering hidden patterns within complex datasets that were otherwise difficult to discern using conventional methods. Furthermore, AI's ability to generalize from learned data to new, unseen situations made it particularly valuable in fields such as physics. The application of AI in physics education was further supported by others (Adams & Wieman, 2007), who argued that it helped distinguish between content knowledge and problem-solving abilities. They proposed that AI-driven tools could provide more accurate assessments of students' problem-solving skills by analyzing their thought processes and providing immediate feedback.

Despite those aforementioned advancements, the adoption of AI in physics is not without challenges. There is a need to address the gap between AI's theoretical capabilities and its practical applications. This gap often stems from the lack of interdisciplinary collaboration, which is crucial for the successful implementation of AI in physics. Additionally, the integration of AI into physics education presents unique challenges, such as the need for educators to adapt their teaching methodologies to include AI-driven tools and techniques.

This paper systematically reviews integration of AI as a tool in physics problem-solving, with a particular focus on educational applications and practical implementations. It fills the gap on a lack of a holistic framework that combines these diverse applications into a cohesive model. This study aims to bridge this gap by reviewing the existing literature as well as incorporating personal experiences using AI tools like ChatGPT in educational and practical settings.

The integration of AI in physics education, as discussed by Zawacki-Richter et al. (2019), showed promise in personalizing learning experiences and providing targeted feedback. However, there is limited research on the method of AI integration into physics curricula to enhance student engagement and improve problem-solving skills. This study addresses this gap by exploring the potential of AI tools like ChatGPT in creating interactive and personalized learning environments.

Research Objectives

The primary objective of this research is to investigate the potential of AI tools in enhancing problem-solving capabilities in physics. This study delves into how personal experiences, particularly the use of ChatGPT, can aid in solving complex physics problems. By examining a wide range of academic sources, the research uncovers the advantages and disadvantages associated with the utilization of AI tools. These insights are essential for understanding the broader impact of AI on the learning and application of physics concepts.

Moreover, the study provides practical recommendations for their effective use. These recommendations are aimed at educators, and students, offering guidance on how to integrate AI tools into their problem-solving processes. It highlights the transformative potential of AI in physics education and underscore the importance of balancing technology with traditional learning methods to maximize educational outcomes.

METHODS

Literature Review Using PRISMA

The methodology involves a systematic literature review following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. It was employed to analyze the latest research trends in the area of problem-solving in physics utilizing AI tools. The primary data source for this review was the SCOPUS database, and the search was conducted using the keyword "AI in Physics Education." The review covered the period from January 2023 to May 25, 2024.

The applied PRISMA methodology consisted of four key stages: identification, screening, eligibility, and inclusion. In the identification stage, relevant research articles were identified in the SCOPUS database using the specified keyword. The search was limited to documents published within the last two years to ensure the inclusion of the most recent research trends. During the screening stage, the identified documents were filtered using specific criteria. Only journal articles and conference proceedings were considered, and the documents had to be written in English. Additionally, the focus was limited to articles within the field of physics to maintain the study's relevance. In the eligibility stage, the documents were further evaluated to ensure they specifically addressed the use of AI tools in physics education. This step was performed manually by selecting articles that aligned with the theme of the study. Articles that did not meet these criteria were excluded from further analysis. Finally, the inclusion stage involved a thorough examination of the eligible articles to identify those that specifically discussed the intervention of AI tools, such as GPT, in physics education.

The selected articles underwent a thorough and detailed analysis, where information pertinent to the authors, study objectives, and study results was meticulously extracted. The extracted data were then comprehensively discussed, with particular emphasis on aligning the findings with the overarching objectives of this study. The analysis aimed to elucidate the connections between the various study outcomes and the specific goals of our research, providing a cohesive understanding of how each article contributed to the broader context of the study. This systematic approach ensured that the discussion remained focused and relevant, highlighting key insights and drawing meaningful conclusions that reinforced the primary aims of our research endeavor.

Exploring Personal Experience Using AI Tools (ChatGPT)

The second objective of this study involved an in-depth exploration of personal experiences using AI tools, with a particular emphasis on ChatGPT. This exploration focused on testing the reliability of ChatGPT in solving physics problems, particularly in the field of thermodynamics, ranging from simple to complex problems. A series of thermodynamics questions were posed to ChatGPT, and each response was meticulously evaluated for accuracy and clarity, providing a comprehensive assessment of its problem-solving capabilities. The results of this rigorous testing process were carefully documented and analyzed to identify the strengths and limitations of using ChatGPT for solving physics problems.

This personal experience was complemented by qualitative data gathered through an interview with a lecturer who actively teaches at a leading university in Southeast Asia. The lecturer, who taught thermodynamics courses for the past three years and actively used ChatGPT as a tool to assist in solving thermodynamics problems, provided valuable insights. The interview was transcribed and became an integral part of the study's discussion, offering practical perspectives on the use of ChatGPT in an educational setting.

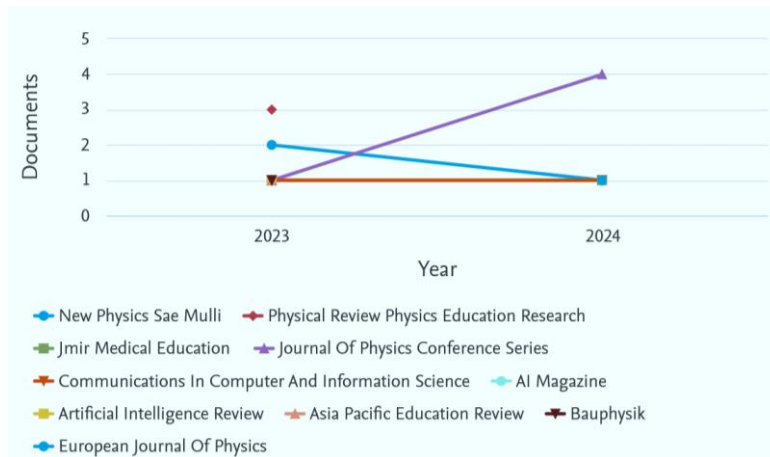
The findings from this personal experience exploration were pivotal in formulating recommendations for the effective use of AI tools. These recommendations were designed to guide both educators and students in seamlessly integrating AI tools into their learning and teaching processes, thereby enhancing their problem-solving skills in physics. Key recommendations included strategies for leveraging ChatGPT's strengths in providing clear explanations and step-by-step solutions, as well as approaches to mitigate its limitations, such as cross-verifying information with traditional resources and using ChatGPT as a supplementary tool rather than a primary source of information.

To provide a comprehensive overview, data from both the literature review and the personal experience exploration were synthesized and discussed. This synthesis involved comparing the theoretical insights gained from the literature with the practical findings from the hands-on exploration of ChatGPT. By integrating these two data sources, the study offered a well-rounded perspective on how AI tools can be effectively utilized.

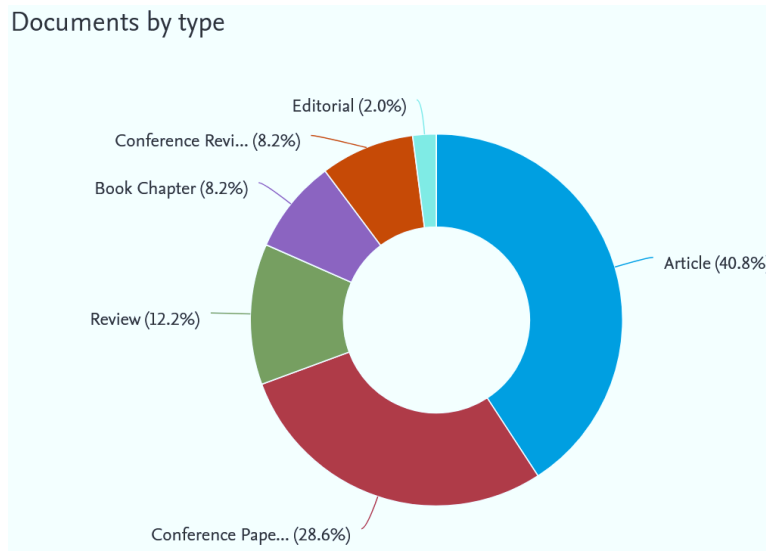
RESULTS AND DISCUSSION

Based on the analysis conducted from January 2023 to May 2024, a total of 49 relevant documents were identified. Of these, 15 documents were published in 2024, while 34 documents were published in 2023. The distribution of documents per year by source is presented in Figure 1. This analysis revealed the publication trends and the sources contributing to the research during this period, providing a clear overview of the development and focus of research within this timeframe.

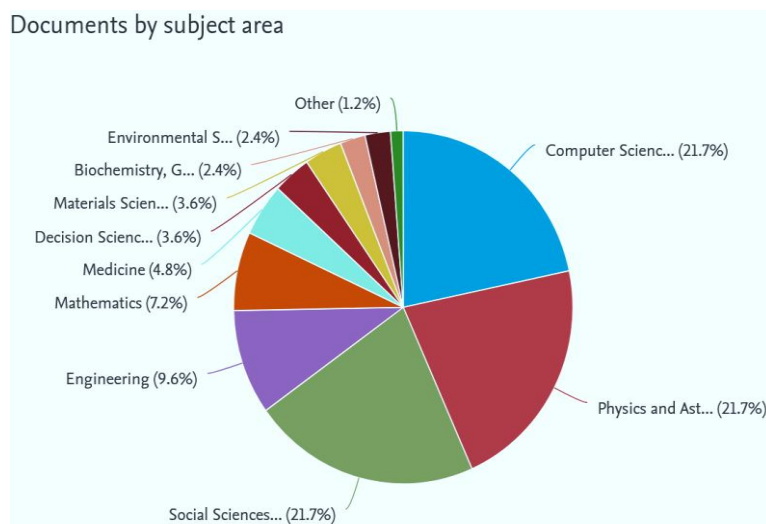
As depicted in Figure 1(a), various journals and conferences contributed to these publications. Notably, journals such as *Physical Review Physics Education Research* and *AI Magazine* played a crucial role, indicating their prominence and relevance in disseminating research related to the integration of AI in physics education. The trend also highlighted a shift in focus towards newer and more interdisciplinary journals like *Artificial Intelligence Review* and *Communications in Computer and Information Science*, indicating the growing intersection of AI and education technologies.



(a)



(b)



(c)

Figure 1. The distribution of documents per year: (a) by source, (b) by type, and (c) by subject area

The distribution of documents by type and subject area, as shown in Figures 1(b) and 1(c), provided further insights into the nature and focus of the research.

Articles constituted the majority of the documents, making up 40.8%, followed by conference papers at 28.6%, and reviews at 12.2%. This indicates a robust engagement in both primary research and scholarly discussions, with a significant portion of the findings being presented in conferences. Book chapters and conference reviews also made up a noticeable part, reflecting a diverse array of publication types. Regarding the subject areas, the research predominantly spanned computer science, physics and astronomy, and social sciences, each contributing 21.7% to the total publications. This balanced distribution suggested a multidisciplinary approach to studying AI's role in physics education, with notable contributions from engineering, and mathematics as well. Such diversity not only highlighted the broad applicability and interest in the subject but also pointed to the collaborative efforts across different scientific disciplines to explore and understand the integration of AI tools in educational settings.

Out of the 49 eligible documents identified in the initial analysis, 14 met the stringent inclusion criteria established for this review. These 14 documents were thoroughly examined and included in the final review, as they were deemed to provide the most relevant and high-quality information pertinent to the research focus. This selection process ensured that the review was comprehensive yet focused, incorporating only the most pertinent studies that contribute significantly to understanding the topic at hand. The inclusion of these documents helped to maintain a high standard of evidence and relevance in the review, ultimately aiming to offer insightful and reliable conclusions. The detailed results and analysis of these selected documents are presented in Table 1, providing a clear and organized summary of the key findings and contributions from these studies.

Table 1. Document details in inclusion criteria

| No | Author(s) | Study objectives | Study results |
|----|-------------------------|--|--|
| 1. | (Clark et al., 2024) | To evaluate ChatGPT-4's utility in enhancing lesson plans for Thomson, Millikan, and Rutherford experiments. | ChatGPT-4 effectively supported lesson planning, but lacked useful visual aids, supporting but not replacing instructors. |
| 2. | (Thaler et al., 2024) | To integrate advance AI and physics through novel AI approaches and community building. | The study successfully developed robust AI tools incorporating physics principles, fostering significant advancements in both fields. |
| 3. | (Yeadon & Hardy, 2024) | To assess GPT-3.5-turbo's performance in answering physics exam questions across educational levels. | AI performed well at GCSE level but struggled with university-level questions, indicating limitations in handling complex physics. |
| 4. | (Piccione et al., 2024) | To introduce innovative teaching methodologies for modern physics topics in the Italian curriculum. | Utilizing AI enhanced teacher capabilities and student engagement using microcontrollers, and web platforms for advanced physics topics. |

| No | Author(s) | Study objectives | Study results |
|-----|----------------------------|--|--|
| 5. | (Ding et al., 2023) | To investigate undergraduate students' perceptions of ChatGPT as a virtual tutor in physics classes. | Despite inaccuracies, students trusted ChatGPT, highlighting the need for improved AI literacy to manage misconceptions. |
| 6. | (Liang et al., 2023) | To explore ChatGPT's pedagogical benefits and prompting techniques for solving physics problems. | ChatGPT effectively solved physics problems, explained solutions, and generated exercises at a human-like level. |
| 7. | (Zhu & Yu, 2023) | To examine the integration of AI and quantum computing to advance both fields. | AI improved quantum algorithms and QC enhanced AI processes, driving innovation in both AI and quantum technology. |
| 8. | (Kieser et al., 2023) | To evaluate ChatGPT's ability to generate synthetic datasets for the Force Concept Inventory. | ChatGPT accurately solved FCI questions and simulated varied preconception-based responses, but not cohort-specific ones. |
| 9. | (Tschisgale et al., 2023) | To apply computational grounded theory to qualitative research in physics education. | CGT combined AI and human analysis effectively, enhancing scalability and reproducibility in qualitative research. |
| 10. | (Muther et al., 2023) | To review physics-informed machine learning (PIML) integration for solving complex physics problems. | PIML provided accurate, explainable models, outperforming traditional methods but requiring substantial computational power. |
| 11. | (Borisova et al., 2023) | To review software applications and AI tools for teaching electric current in physics. | Tinkercad and ChatGPT enhanced students' understanding and supported self-training in electric circuit modeling. |
| 12. | (K. D. Wang et al., 2023) | To investigate ChatGPT's ability to solve college-level engineering physics problems. | ChatGPT solved 62.5% of well-specified problems but only 8.3% of under-specified ones, highlighting its limitations. |
| 13. | (Mahligawati et al., 2023) | To explore AI's applications, benefits, and challenges in physics education. | AI enhanced understanding, personalized instruction, and assessment but faced challenges in infrastructure and ethical considerations. |
| 14. | (Rico et al., 2023) | To evaluate AI's ability to assess engineering students' understanding of acceleration. | AI showed 44% similarity with expert answers, identifying conceptual gaps and varying levels of student understanding. |

The review results presented in Table 1 show the integration of AI tools in physics education showed significant potential for enhancing problem-solving skills and personalizing learning experiences. Research indicated that tools like ChatGPT could support lesson planning and innovative teaching methodologies, though they were not yet advanced enough to replace human instructors, particularly for high-complexity content. These tools excelled in addressing lower-level physics questions and providing educational exercises, contributing positively to both teaching and learning environments. However, challenges remained, including the need for substantial computational power, handling under-specified problems, and addressing ethical and infrastructural issues. Despite these hurdles, the combination of AI with other technologies, such as quantum computing, continued to drive innovation. For AI tools to be most effective, there should be a balanced integration with traditional teaching methods and improved AI literacy among educators and students. Based on Table 1, several advantages and disadvantages of using AI in physics are discussed further.

Advantages of Using AI in Physics

AI has brought transformative advantages to physics education, enhancing both teaching and research. One notable application is in the development and refinement of lesson plans. Instructors using AI tools like ChatGPT-4 have reported significant improvements in their instructional strategies for teaching historical experiments, such as those by Thomson, Millikan, and Rutherford. ChatGPT-4 was found effective in outlining lesson plans, recommending resources, discussing instructional strategies, and generating assessments, which supports educators in delivering more comprehensive and tailored instruction to students (Clark et al., 2024). Similarly, the integration of AI into lesson planning and educational support extended to more advanced and specialized topics. For instance, in Italian physics curricula, AI tools and microcontroller development boards were employed to teach complex subjects like climate change, space missions, and Einstein's relativity, which are not typically covered in traditional courses. This integration made these topics more accessible and engaging for students, fostering a deeper understanding and interest in modern physics (Piccione et al., 2024).

The use of AI in physics education is not limited to lesson planning but extends to practical applications and problem-solving. AI models like GPT-3.5-turbo were evaluated for their ability to answer physics exam questions across different educational levels. The model demonstrated high proficiency at the GCSE level, although its performance decreased with more advanced questions. This variability highlights AI's potential to assist in early education while underscoring the need for continued development to handle more complex problems (Yeadon & Hardy, 2024). Additionally, AI's role in practical learning environments, such as Tinkercad for modeling electric circuits, had streamlined the learning process by allowing students to visualize and interact with physical laws and phenomena directly. This practical application was proven particularly valuable in subjects that require hands-on experimentation and observation (Borisova et al., 2023).

AI's impact is also seen in advanced research and the intersection of physics and other scientific fields. The NSF AI Institute for Artificial Intelligence and Fundamental Interactions (IAIFI) is a prime example, where AI is combined with fundamental physics principles to tackle some of the most challenging problems in

the field. This collaboration was only advanced AI technologies but also enriched our understanding of physics, enabling significant discoveries and fostering a community that bridges both disciplines (Thaler et al., 2024). Furthermore, AI was leveraged to enhance quantum computing (QC) by developing algorithms that improve the control of quantum systems, a notoriously difficult task. AI techniques provided new insights and solutions in quantum physics, thereby accelerating the discovery of quantum laws and applications (Zhu & Yu, 2023). In educational contexts, AI showed potential in generating synthetic datasets for physics concept inventories, such as the Force Concept Inventory (FCI), to study and improve student understanding of fundamental physics concepts. AI-generated responses could simulate student answers, helping educators identify and address common misconceptions (Kieser et al., 2023).

In addition to these applications, AI has been shown instrumental in qualitative research within physics education. Techniques such as computational grounded theory (CGT) integrated AI's pattern detection capabilities with human interpretative skills to analyze large datasets, providing scalable and reproducible methods for qualitative research. This approach allowed for deeper insights into student problem-solving processes and educational outcomes (Tschisgale et al., 2023). Moreover, physics-informed machine learning (PIML) combined physical laws with machine learning algorithms to solve complex physics-driven problems, offering more accurate and explainable models compared to traditional data-driven approaches. This integration ensured that AI models adhere to physical principles, enhancing their reliability and application in scientific research (Muther et al., 2023). Overall, the diverse applications and significant advantages of AI in physics and physics education highlighted its transformative potential, driving innovation and improving educational practices across the field (Ding et al., 2023; Liang et al., 2023; Mahligawati et al., 2023; Wang et al., 2023; Rico et al., 2023).

Disadvantages of Using AI in Physics

Despite the numerous advantages AI brings to physics and physics education, several significant disadvantages and limitations warrant attention. One of the primary concerns is the accuracy and reliability of AI-generated content. For instance, studies showed that while GPT-3.5-turbo performed well on simpler tasks like GCSE-level physics questions, its accuracy declined significantly with more advanced content, such as A-Level and university-level questions. The model scored an average of 83.4% on GCSE questions but only 37.4% on university-level questions, highlighting its limitations in handling complex and higher-level physics problems (Yeadon & Hardy, 2024). Additionally, when assessed as a marking tool, the AI exhibited notable inaccuracies, especially in marking straightforward questions like multiple-choice ones, with an average concordance with human markers of only 50.8%. This inconsistency posed a challenge for educators relying on AI for accurate assessment and feedback (Yeadon & Hardy, 2024).

Another significant drawback is AI's inability to generate useful visual aids, which are crucial in teaching physics concepts that often require graphical representations. While ChatGPT-4 was found effective in outlining lesson plans and providing explanations, it failed to create images or visual aids that instructors could find useful, limiting its effectiveness in a comprehensive educational setting (Clark et al., 2024). Furthermore, AI's performance in practical applications, such as solving

under-specified, real-world physics problems, was suboptimal. For example, ChatGPT's accuracy dropped to a mere 8.3% for under-specified problems, revealing its struggle to construct accurate models of the physical world and make reasonable assumptions about missing data (Wang et al., 2023). This limitation is critical in STEM education, where real-world problem-solving skills are essential.

Trust and overreliance on AI tools present another set of challenges. Despite GenAI's inaccuracies in answering physics questions, most students tended to trust its outputs, which led to misconceptions and overreliance on AI-generated solutions (Ding et al., 2023). This misplaced trust was particularly concerning as AI models like ChatGPT often produce outputs that sound plausible but were incorrect, leading students to accept incorrect information without proper verification (Ding et al., 2023). Moreover, the AI's tendency to generate verbose and sometimes irrelevant responses further complicated its utility in educational contexts. For example, while evaluating ChatGPT's use in solving physics problems, researchers found that it often showcased novel methods not included in the syllabus and exhibited verbosity and miscalculations, especially in basic arithmetic (Yeadon & Hardy, 2024).

The integration of AI into physics education also raises concerns related to technical infrastructure, teacher training, data privacy, and ethical considerations. Implementing AI technologies required substantial technical infrastructure, which might not be readily available in all educational institutions (Mahligawati et al., 2023). Teachers also required adequate training to effectively use AI tools, which could be a significant hurdle given the rapid pace of AI development and the existing workload on educators (Mahligawati et al., 2023). Data privacy and ethical considerations are paramount, especially when dealing with student data and AI's decision-making processes. The use of AI in education should ensure compliance with data privacy laws and address ethical concerns related to bias and fairness (Mahligawati et al., 2023).

Furthermore, while AI's integration with quantum computing has shown promise, controlling quantum systems remains a significant obstacle. AI techniques, although helpful, were not yet fully reliable for the automated control of complex quantum systems, posing a barrier to widespread QC application (Zhu & Yu, 2023). Similarly, while AI could generate synthetic datasets for educational research, such as the FCI, it often fails to simulate the variability in responses that would be expected from different student cohorts, limiting its effectiveness in creating realistic educational scenarios (Kieser et al., 2023). Overall, while AI offers substantial benefits in physics education, its disadvantages, including accuracy issues, limitations in practical applications, overreliance by students, technical and ethical challenges, and reliability concerns in advanced applications, must be carefully considered and addressed to fully leverage its potential.

Personal Experience Using AI Tools

By directly testing ChatGPT's responses to a series of thermodynamics questions, the accuracy and clarity of these responses were meticulously assessed, highlighting both the strengths and limitations of the AI in problem-solving. The evaluation results of ChatGPT's performance in solving thermodynamics problems are presented, with an example of its responses to simple thermodynamic problems illustrated in Figure 2.

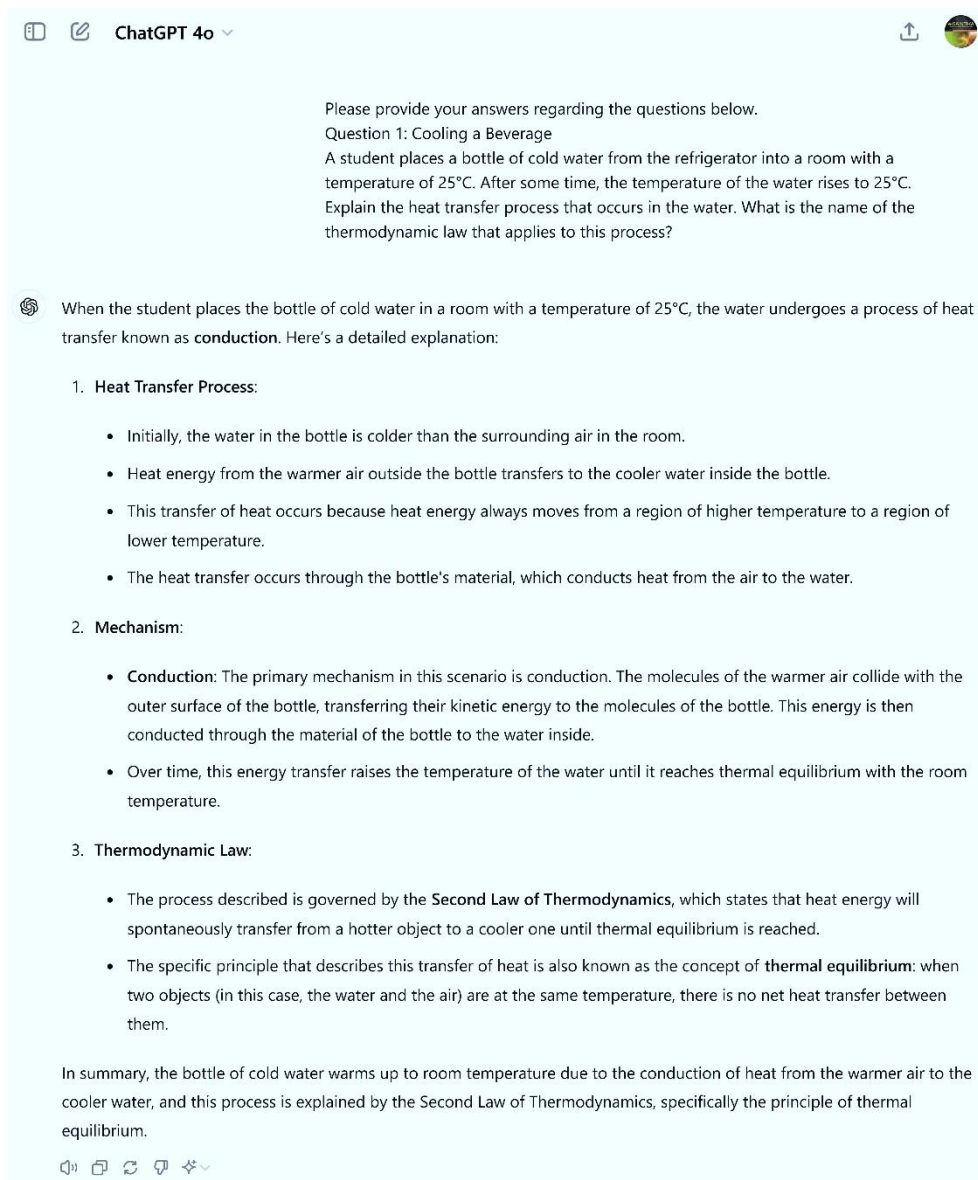


Figure 2. ChatGPT responses in solving simple thermodynamic problems

In the first case (cooling a beverage), ChatGPT provided an excellent response to questions related to solving simple thermodynamic problems. It elaborated comprehensively on the heat transfer process by detailing how heat energy moves from a region of higher temperature (the room) to a region of lower temperature (the bottle of cold water). ChatGPT clarified that the molecules of air surrounding the bottle transfer their kinetic energy to the bottle's material, which in turn warms the water inside the bottle. This process continues until thermal equilibrium is reached. Moreover, ChatGPT effectively tied this heat transfer process to the relevant thermodynamic principles. It specifically mentioned the Second Law of Thermodynamics, explaining that heat energy naturally moves from a hotter object to a cooler one until equilibrium is attained. By providing this detailed yet concise summary, ChatGPT not only demonstrated its understanding of the scientific concepts but also made the information easy to understand. Subsequently, ChatGPT was employed to solve thermodynamic problems through calculations, and the results were presented in Figure 3.

ChatGPT 4o

Please provide your answers regarding the questions below.
 Question 2: Heating Water
 A person is boiling water using an electric heater with a power of 1000 W. If they want to heat 1 liter of water (mass of water 1 kg) from 25°C to boiling point (100°C), how long will it take? (Given: Specific heat capacity of water = 4200 J/kg°C)

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To determine how long it will take to heat 1 liter of water from 25°C to 100°C using an electric heater with a power of 1000 W, we can use the following formula:

$$Q = mc\Delta T$$

Where:

- Q is the heat energy required (in joules, J)
- m is the mass of the water (in kilograms, kg)
- c is the specific heat capacity of water (in joules per kilogram per degree Celsius, J/kg°C)
- ΔT is the change in temperature (in degrees Celsius, °C)

First, we calculate the heat energy required:

$$Q = mc\Delta T$$

Given:

- $m = 1 \text{ kg}$
- $c = 4200 \text{ J/kg}^\circ\text{C}$
- $\Delta T = 100^\circ\text{C} - 25^\circ\text{C} = 75^\circ\text{C}$

So:

$$Q = 1 \text{ kg} \times 4200 \text{ J/kg}^\circ\text{C} \times 75^\circ\text{C}$$

$$Q = 315,000 \text{ J}$$

Next, we need to find the time it takes to supply this amount of energy using a 1000 W heater. Power (P) is defined as energy per unit time:

$$P = \frac{Q}{t}$$

Rearranging for t :

$$t = \frac{Q}{P}$$

Given:

- $Q = 315,000 \text{ J}$
- $P = 1000 \text{ W}$ (1 W = 1 J/s)

So:

$$t = \frac{315,000 \text{ J}}{1000 \text{ W}}$$

$$t = 315 \text{ seconds}$$

Therefore, it will take 315 seconds (or 5 minutes and 15 seconds) to heat 1 liter of water from 25°C to 100°C using a 1000 W electric heater.

Figure 3. ChatGPT responses in solving thermodynamic problems in the form of calculations

The results presented in Figure 3 demonstrate that ChatGPT is reliable for solving thermodynamic problems through calculations. ChatGPT initiated its

response by presenting the heat energy formulation and proceeds to solve the problem until it arrived at the requested solution, indicating its dependability in handling thermodynamic calculations. Furthermore, Figure 4 illustrates ChatGPT's responses in solving thermodynamic problems, specifically in understanding ideal gas graphs.

ChatGPT 4o
📄 📧 📤

Please provide your answer to the following question.
 Question 3: An ideal gas undergoes a cyclic process as shown in the p-V graph (see Figure). Determine the work done from A to B, the work done from B to C, the work done from C to A, and the net work done by the gas in one cycle.

🌀 To determine the work done by the gas in the cyclic process shown in the p-V graph, we need to analyze each segment of the cycle separately.

1. Work done from A to B (Isothermal Process)

In an isothermal process, the work done by the gas can be calculated using the formula:

$$W_{AB} = nRT \ln \left(\frac{V_B}{V_A} \right)$$

However, since we do not have the temperature or the number of moles, we can also use the area under the curve if the process is isothermal and the curve is known.

2. Work done from B to C (Isochoric Process)

In an isochoric process (constant volume), the work done is zero because the volume does not change.

$$W_{BC} = 0$$

3. Work done from C to A (Isobaric Process)

In an isobaric process, the work done by the gas can be calculated using the formula:

$$W_{CA} = P \Delta V$$

Where P is the constant pressure, and ΔV is the change in volume.

$$W_{CA} = P(V_A - V_C)$$

Given that $P = 10^5 \text{ Pa}$ (constant pressure from 1 to $3 \times 10^5 \text{ Pa}$):

$$W_{CA} = 1 \times 10^5 \text{ Pa} \times (2 \text{ L} - 6 \text{ L})$$

$$W_{CA} = 1 \times 10^5 \text{ Pa} \times (-4 \text{ L})$$

$$W_{CA} = -4 \times 10^5 \text{ J}$$

4. Net Work Done in One Cycle

The net work done in one complete cycle is the area enclosed by the path ABC on the p-V diagram. This can be calculated as the area of the rectangle minus the area under the curve (if applicable).

Area of rectangle (A to B to C to A):

$$\text{Area}_{\text{rectangle}} = (V_B - V_A) \times (P_A - P_C)$$

$$\text{Area}_{\text{rectangle}} = (6 \text{ L} - 2 \text{ L}) \times (3 \times 10^5 \text{ Pa} - 1 \times 10^5 \text{ Pa})$$

$$\text{Area}_{\text{rectangle}} = 4 \text{ L} \times 2 \times 10^5 \text{ Pa}$$

$$\text{Area}_{\text{rectangle}} = 8 \times 10^5 \text{ J}$$

Therefore, the net work done by the gas in one cycle is the area enclosed by the path ABCD.

$$W_{\text{net}} = 8 \times 10^5 \text{ J}$$

Figure 4. ChatGPT responses in solving thermodynamic problems (understanding ideal gas graphs)

The response of ChatGPT in Figure 4 indicates a lack of precision in interpreting the graph, where ChatGPT incorrectly identified the transition from point A to B as an isothermal process and the transition from point C to A as an isobaric process. This error might be attributed to the potentially inaccurate depiction of the graph provided by the user or possibly due to the inadequacy or lack of comprehensiveness of the question presented. Such misinterpretations highlighted the importance of clear and precise visual aids and questions to ensure accurate analysis and responses by AI systems like ChatGPT. Previous studies showed that while ChatGPT had the potential to revolutionize education in various ways, it also comes with limitations and can make mistakes, which can lead to additional issues (Araújo & Saúde, 2024). Understanding these limitations was essential for educators to effectively integrate ChatGPT into their teaching practices (EISayary, 2024).

By rigorously evaluating ChatGPT's responses to a range of thermodynamics questions, the study meticulously assessed the accuracy and clarity of these responses, thereby highlighting both the strengths and limitations of the AI in problem-solving. The findings from personal experiences utilizing ChatGPT in solving physics problems were complemented by the results of an interview with a thermodynamics lecturer. A summary of the interview findings is presented in Table 2.

Table 2. The Interview results on the use of ChatGPT in teaching thermodynamics

| No | Interviewer | Lecturer responses |
|----|--|---|
| 1. | What was your initial experience utilizing ChatGPT in the instruction of Thermodynamics? | "My initial experience employing ChatGPT in the instruction of Thermodynamics was quite enlightening. I initially used the tool to generate illustrative examples and explanations for complex concepts such as the laws of thermodynamics and entropy. I discovered that ChatGPT could provide diverse perspectives and simplify intricate topics, facilitating better comprehension among students." |
| 2. | What is the primary rationale for selecting ChatGPT as an instructional tool? | "The primary rationale for selecting ChatGPT as an instructional tool lies in its ability to deliver instant, and varied explanations. It serves as a supplemental resource that can address students' queries in real-time, thereby enhancing the interactivity and engagement of the learning experience. Additionally, its capability to present information in multiple formats, including text summaries, detailed explanations, and examples, makes it an invaluable asset in my teaching arsenal." |
| 3. | How does ChatGPT assist in elucidating complex Thermodynamics concepts to students? | "ChatGPT assists by deconstructing complex concepts into more manageable segments. For instance, when elucidating the second law of thermodynamics, it can provide multiple analogies and real-world examples that render the abstract idea more concrete. Furthermore, it can respond to follow-up questions from students, reinforcing their understanding through interactive dialogue." |

| No | Interviewer | Lecturer responses |
|----|--|---|
| 4. | Have you encountered any limitations or challenges when utilizing ChatGPT in teaching Thermodynamics? If so, how do you address them? | "Yes, there have been certain limitations. One challenge is that ChatGPT occasionally offers overly simplified answers or lacks context-specific details essential for higher-level comprehension. To address this, I consistently review and supplement its responses with additional explanations and examples tailored to the specific needs of my students. Moreover, I encourage students to critically evaluate the information provided by ChatGPT and seek clarification when necessary." |
| 5. | How does ChatGPT contribute to the design of assignments or quizzes for students? | "ChatGPT contributes to the design of assignments and quizzes by generating diverse questions that encompass different aspects of thermodynamics. It can create both conceptual questions and numerical problems, ensuring a comprehensive assessment of students' understanding. Additionally, it can assist in drafting detailed solutions and explanations, which I use to guide students through their learning process." |
| 6. | Do you believe ChatGPT can supplant certain aspects of traditional teaching? Why or why not? | "While ChatGPT can enhance certain aspects of traditional teaching, I do not believe it can completely supplant them. Human interaction and personalized guidance are irreplaceable components of effective teaching. ChatGPT is a valuable tool for supplementing instruction and providing additional resources, but it cannot replicate the mentorship, emotional support, and nuanced feedback that a human educator offers." |
| 7. | What are your aspirations for the further development of technologies like ChatGPT in the realm of education, particularly in the instruction of Thermodynamics? | "I hope that technologies like ChatGPT will continue to evolve, becoming even more sophisticated in understanding and generating context-specific educational content. Enhanced capabilities in personalized learning, where AI can adapt to the unique needs and learning styles of each student, would be particularly beneficial. For thermodynamics specifically, improvements in the ability to visualize complex phenomena and simulate real-world scenarios would greatly enrich the learning experience." |

The findings from the rigorous evaluation of ChatGPT's responses to thermodynamics questions, supplemented by an interview with a thermodynamics lecturer, revealed significant insights into the use of AI in educational contexts, particularly in teaching complex subjects like thermodynamics. Results in Table 2 highlights that ChatGPT can provide accurate and clear explanations for a range of thermodynamics concepts, such as the laws of thermodynamics and entropy. The AI's ability to generate illustrative examples and explanations aided in simplifying intricate topics, which facilitated better student comprehension. However, the lecturer noted that while ChatGPT was proficient in deconstructing complex

concepts into more manageable segments, it occasionally offered overly simplified answers or lacks context-specific details essential for higher-level comprehension. This limitation necessitated that educators review and supplement ChatGPT's responses to ensure completeness and accuracy. As noted in previous studies, ChatGPT showcased both promising perspectives and valid concerns (Sallam, 2023). While ChatGPT excelled in prompting and engaging in natural conversations without complex natural language processing (Xu et al., 2024), its ability to generate information of moderate quality was noted in specific contexts (Fahy et al., 2024).

One of the primary rationales for selecting ChatGPT as an instructional tool is its ability to deliver instant and varied explanations, which enhances the interactivity and engagement of the learning experience. This AI application could address student queries in real-time, offering various formats of information presentation like text summaries, detailed explanations, and examples (Tlili et al., 2023). By engaging in interactive dialogues, ChatGPT supplemented traditional teaching methods, aiding in better understanding through dynamic exchanges (Guha et al., 2024). Educators could leverage ChatGPT to reduce time spent on routine tasks, allowing for more focus on cognitively demanding or creative activities (Guha et al., 2024).

ChatGPT's contribution to the design of assignments and quizzes is another notable strength. The AI could generate diverse questions encompassing different aspects of thermodynamics, including both conceptual and numerical problems. It ensured a comprehensive assessment of students' understanding. Additionally, ChatGPT assisted in drafting detailed solutions and explanations, which educators can use to guide students through their learning process. This functionality supported the creation of more dynamic and varied instructional materials, enhancing the overall teaching and learning experience. While ChatGPT proved beneficial in education, it was essential to note its limitations. For instance, it might struggle with mathematical operations, made conceptual errors, and provided partially accurate information in citations (Tyson, 2023). Teachers should play a crucial role in integrating tools like ChatGPT effectively into literacy instruction to foster critical thinking among students (Hutchison, 2024).

Despite its strengths, the interview resulted identifies several limitations and challenges associated with using ChatGPT in teaching thermodynamics. The primary challenge was the occasional provision of overly simplified answers or lack of context-specific details. To address this, educators should consistently review and supplement ChatGPT's responses with additional explanations and examples tailored to the specific needs of their students (Eysenbach, 2023). Encouraging students to critically evaluate the information provided by ChatGPT and seek clarification when necessary was also crucial (Eysenbach, 2023).

While ChatGPT enhances certain aspects of traditional teaching, the lecturer emphasized that it cannot completely supplant human interaction and personalized guidance, which are irreplaceable components of effective teaching. ChatGPT was a valuable tool for supplementing instruction and providing additional resources (Harry, 2023; Song, 2024; Wang et al., 2023), but it could not replicate the mentorship, emotional support, and nuanced feedback that a human educator offers (Kucirkova & Leaton-Gray, 2023). Overall, it suggested the importance of

integrating AI tools like ChatGPT into the broader educational framework rather than viewing them as replacements for traditional teaching methods.

Looking forward, there are aspirations for the further development of technologies like ChatGPT in education. The lecturer hopes that these technologies will evolve to become even more sophisticated in understanding and generating context-specific educational content. Enhanced capabilities in personalized learning, where AI can adapt to the unique needs and learning styles of each student, would be particularly beneficial. For thermodynamics specifically, improvements in the ability to visualize complex phenomena and simulate real-world scenarios would greatly enrich the learning experience.

In conclusion, while ChatGPT demonstrates significant potential in enhancing the teaching and learning of physics, especially thermodynamics, it is essential to recognize and address its limitations. By integrating AI tools thoughtfully and supplementing them with human expertise, educators can leverage these technologies to create more effective and engaging educational experiences.

CONCLUSION

This study highlights the significant impact of AI tools in enhancing problem-solving capabilities and personalizing learning experiences in physics education. Through a systematic literature review following the PRISMA methodology, we identified the latest research trends and practical implementations of AI tools like ChatGPT in physics education. The study revealed that AI tools have become instrumental in supporting lesson planning, providing innovative teaching methodologies, and assisting in solving complex physics problems. These tools have shown potential in enhancing both teaching and learning environments, although they still face challenges in addressing higher-level content and context-specific details.

The advantages and disadvantages of using AI in physics education were thoroughly examined. On the positive side, AI tools like ChatGPT have been proven effective in simplifying complex concepts, offering real-time explanations, and generating diverse educational content. These tools were proven valuable in creating dynamic and varied instructional materials, aiding in better student comprehension and engagement. However, limitations such as the occasional provision of overly simplified answers, lack of useful visual aids, and inaccuracies in handling complex problems were identified. Addressing these challenges would require educators to supplement AI responses with additional explanations and encourage critical evaluation among students.

Personal experiences with AI tools, particularly ChatGPT, were explored through direct testing and an interview with a thermodynamics lecturer. The findings suggest ChatGPT's ability to provide accurate and clear explanations for various thermodynamics concepts, enhancing student understanding. However, the study also highlighted the need for human intervention to review and supplement AI-generated content to ensure completeness and accuracy. The lecturer emphasized that while AI tools can enhance certain aspects of traditional teaching, they cannot completely replace the mentorship, emotional support, and nuanced feedback provided by human educators. The future development of AI technologies in education should focus on personalized learning, improved

visualization of complex phenomena, and the seamless integration of AI with traditional teaching methods to maximize educational outcomes in physics.

RECOMMENDATION

Based on the findings of this study, it is recommended that educators integrate AI tools like ChatGPT into physics education to enhance problem-solving skills and personalize learning experiences while being mindful of their limitations. Educators should supplement AI-generated content with additional explanations and visual aids, ensuring accuracy and context-specific details. It is crucial to foster critical evaluation skills among students to manage misconceptions and prevent overreliance on AI. Future developments in AI should focus on personalized learning adaptations, improved visualization capabilities, and the integration of AI with traditional teaching methodologies to fully leverage the potential of AI in physics education.

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