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Bridging Pedagogical Gaps: How Teachers Can Use ChatGPT to Support Physics Experiments

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Abstract
The integration of artificial intelligence in education is reshaping instructional methods, with ChatGPT emerging as a highly adaptable tool. This research explores the potential of ChatGPT to address pedagogical shortcomings in physics education, particularly in experiential learning. Physics experiments are vital for fostering inquiry skills, conceptual understanding, and scientific literacy; however, their execution is often limited by time, resources, and teacher preparedness. Drawing on recent literature, this article demonstrates how ChatGPT can support all stages of the experimental process—including design, hypothesis formation, real-time guidance, and data analysis. The study highlights ChatGPT's role in promoting inclusivity through adaptive explanations, multilingual support, and differentiated resources. Additionally, the tool offers opportunities for teacher professional development, such as resource generation and reflective practice. Ethical concerns—including accuracy, bias, data privacy, and overreliance—are critically examined. The article argues that when integrated thoughtfully within constructivist and socio-constructivist frameworks, ChatGPT can enhance experimental physics education, making it more engaging, inclusive, and future-ready.

Keywords: ChatGPT, Physics Education, Experimentation, Artificial Intelligence, Teacher Professional Development

1. Introduction

Recent years have seen growing interest in the use of artificial intelligence (AI) to enhance science education and address persistent learning challenges. ChatGPT, in particular, has attracted attention for its ability to support interactive dialogue, generate educational content, and assist both teachers and students in experimental contexts. This is especially relevant in physics education, where abstract concepts and hands-on experimentation often reveal pedagogical gaps that traditional methods struggle to fill. Although physics experiments are essential for developing scientific reasoning and inquiry skills, their implementation is frequently constrained by limited time, funding, and teacher confidence. Integrating ChatGPT into this domain offers a promising avenue to address these challenges while preparing students for technology-rich learning environments.

Pedagogical gaps in physics education often arise from a mismatch between diverse student needs and the constraints of conventional teaching. Many students find abstract concepts—such as Newtonian mechanics, electromagnetism, and wave phenomena—inaccessible without experimental and dialogic support. Teachers, meanwhile, often struggle to design lab activities that are both educationally effective and practically feasible. Research suggests that AI can help address these issues by supporting experimental design, providing real-time feedback, and creating resources that cater to varying cognitive levels [1, 2]. In this context, ChatGPT has emerged as a versatile pedagogical aid, capable of helping formulate hypotheses, suggesting methodologies, and facilitating critical analysis.

Kotsis [3] has highlighted the role of ChatGPT in supporting hands-on physics experiments in primary education, showing that its interactive features can create a dialogic space for student inquiry and theory-practice connections. Further studies illustrate how ChatGPT can reduce teachers' preparation time, offer structured guidance, and adapt experiments to different student groups [4, 5]. It has also been shown to generate experiment worksheets that promote systematic inquiry and learner autonomy [6]. Together, these studies underscore ChatGPT's flexibility in enriching experimental physics education.

Despite these promising developments, the pedagogical integration of ChatGPT must be considered within broader theoretical and ethical frameworks. Theoretically, ChatGPT aligns with constructivist and socio-constructivist approaches, promoting active knowledge construction through interaction and reflection [7]. It can also support inquiry-based learning, which fosters higher-order thinking. However, concerns have been raised regarding the accuracy of AI-generated content, the risk of reinforcing misconceptions, and the potential reduction in teacher-student interaction [8, 9]. Ethical issues—such as data privacy, algorithmic bias, and transparency—also require careful attention [10, 11].

This article examines how ChatGPT can be effectively integrated into physics experimentation to address pedagogical gaps and enhance science education. It explores applications in experimental design, hypothesis formation, real-time feedback, and data analysis, while also considering implications for diverse learners and teacher professional development. By situating the discussion within current debates on educational technology, this review offers a balanced perspective on the opportunities and challenges of using AI in physics education. It argues that, with strategic and critical implementation, ChatGPT can help make experimental physics more inclusive, engaging, and effective.

This article takes the form of a conceptual review, synthesizing recent international research to illustrate how ChatGPT can support the planning, execution, and evaluation of physics experiments. It brings together theoretical perspectives, practical applications, and ethical considerations to provide a comprehensive understanding of ChatGPT's potential in bridging pedagogical gaps in experimental physics education.

2. Theoretical Framework

The integration of AI in education is best understood through the lens of learning theories that underpin contemporary pedagogy. In physics education, constructivist and socio-constructivist theories have been particularly influential, emphasizing active engagement, inquiry, and collaborative knowledge building. Constructivism posits that learners construct knowledge based on prior experiences, with teachers acting as facilitators. Socio-constructivism, drawing on Vygotsky, highlights the role of social interaction, dialogue, and scaffolding in learning. Both perspectives view experimentation as central to developing scientific literacy, requiring students to test, revise, and reconstruct understanding through practical investigation.

Within these frameworks, ChatGPT can be viewed as an instructional tool. Its dialogic capabilities allow it to act as a collaborator in inquiry—providing feedback, probing student thinking, and tailoring explanations. Research indicates that such interactions can enhance metacognitive awareness and support the gradual understanding of complex concepts [9]. ChatGPT can also reduce cognitive load by guiding procedural steps, freeing students to focus on conceptual learning [7]. These features align closely with the constructivist emphasis on scaffolding and the socio-constructivist view of learning as a socially mediated process.

Recent studies illustrate ChatGPT's potential in supporting physics experimentation. Kotsis [3, 5] demonstrated its utility in primary-level experiments, where it can prompt inquiry, correct misconceptions, and strengthen theory-practice links. Kotsis [4] also showed that ChatGPT can help teachers prepare and implement experiments through structured outlines and adaptable activity variants, reducing planning time and building teacher confidence. Additionally, ChatGPT can serve as a teaching assistant, offering explanations, strategies, and differentiation support [5]. Its ability to generate worksheets further enhances reflective inquiry and student engagement [6].

These contributions can be contextualized within broader discussions on digital pedagogy. Bannert *et al.* [10] argue that multimodal large language models represent a significant advance in science education, enabling simulations that combine text, visuals, and interaction. This extends socio-constructivist principles into multimodal learning environments. Latif *et al.* [2] showed that AI-powered systems like the Physics Assistant robot can act as interactive lab partners, expanding the notion of scientific inquiry beyond physical equipment.

However, theoretical frameworks also caution against uncritical adoption. While AI dialogue systems can support learning, they may also perpetuate misconceptions if their outputs are inaccurate or lack context [8]. Polverini *et al.* [12] compared GPT-4o to university students on the BEMA diagnostic, finding that although the model performed near-expert levels, it occasionally echoed common student misunderstandings. This highlights both the potential of AI for conceptual diagnosis and the need for teacher mediation. Constructivist pedagogy requires careful scaffolding aligned with learner development, and socio-constructivism emphasizes that AI cannot replace the relational aspects of teaching. Ethical integration must also ensure equity, inclusivity, and transparency [11].

In summary, ChatGPT should not replace teachers or physical experiments, but rather serve as an educational partner that enhances constructivist and socio-constructivist approaches in a digital age. By scaffolding inquiry, personalizing feedback, and supporting both teachers and students, ChatGPT can help address pedagogical gaps. Successful integration depends on critical reflection, ongoing teacher development, and ethical guidelines that ensure AI serves a supportive—not substitutive—role.

3. Capabilities of ChatGPT for Physics Education

ChatGPT offers several capabilities that can transform physics teaching and learning. As a advanced language model, it enables dynamic interaction beyond static textbooks or pre-built simulations, providing real-time, adaptive explanations, guidance, and feedback. These features are especially valuable in physics, where abstract concepts, symbolic representations, and experimental design often challenge students. ChatGPT acts as both a cognitive scaffold and pedagogical aid, helping bridge theory, practice, and comprehension.

Recent research on multimodal chatbots suggests they can assist students in interpreting standard physics representations—such as kinematic graphs and circuit diagrams—opening new possibilities for visual sense-making, though teacher guidance remains essential to address reasoning gaps [13]. For example, Polverini and Gregorcic [13] found that GPT-4 with vision input could approach student-level performance on the TUG-K diagnostic, indicating both promise and persistent challenges in conceptual reasoning.

A key capability is ChatGPT's ability to generate adaptive explanations. Unlike uniform textbook content, it tailors responses to learners' prior knowledge, misconceptions, and pace. This personalization can improve understanding and support gradual mastery of complex topics like hydrostatics, motion, and energy transfer [1]. Kotsis [5] notes that ChatGPT can function as a teaching assistant, clarifying student questions and rephrasing concepts in accessible language, thereby helping teachers differentiate instruction.

ChatGPT also supports experimental design and implementation. Many teachers, especially at the primary level, lack confidence in designing and managing lab activities. Kotsis [3, 5] found that ChatGPT can provide procedural instructions, safety tips, and prompts that keep inquiry on track. Kotsis [4] showed how teachers can use it to create structured experiment outlines and resource-appropriate variants, making inquiry-based learning more feasible, particularly in under-resourced schools.

Another contribution is ChatGPT's capacity to generate educational materials. Teachers can prompt it to create worksheets, guiding questions, or activity sequences that support systematic engagement with experiments. Kotsis [6] demonstrated that such resources can boost student autonomy while saving teachers preparation time. These materials serve as drafts that educators can adapt to their specific needs, enhancing productivity and enabling more advanced pedagogical interactions.

Moreover, ChatGPT can provide real-time feedback and scaffolding during experiments. Immediate responses to student questions help prevent misconceptions from taking root [2]. ChatGPT can answer queries, suggest troubleshooting steps, and prompt reflection on results, fostering a constructivist learning environment where students actively refine their hypotheses. This aligns with socio-constructivist views of dialogue as a driver of cognitive development [7].

Finally, ChatGPT promotes critical thinking and scientific reasoning. It encourages students to formulate hypotheses, justify predictions, and analyze evidence, engaging them in the epistemic practices of science. Santos [14] observed that ChatGPT, Bing Chat, and Bard can act as "agents-to-think-with," supporting reflective inquiry. Steinert *et al.* [15] emphasized the role of large language models in providing formative feedback that stimulates metacognition. Mills [16] showed that a custom GPT model offering feedback on lab reports helped students refine their thinking and communication. These skills are essential to physics education, where critical thinking and problem-solving are central to scientific literacy.

However, these capabilities depend on teacher expertise and ethical oversight. Chen *et al.* [8] and Cai *et al.* [9] caution that AI systems can produce incorrect or misleading information if not monitored, and students may lack the skills to detect errors. Issues of bias, data privacy, and overreliance must also be addressed [10, 11]. These concerns highlight the need for pedagogical frameworks that prioritize transparency, inclusivity, and teacher facilitation.

In summary, ChatGPT offers multiple capabilities that can significantly enhance physics education—through adaptive explanations, experimental support, material generation, and inquiry stimulation. Its integration should be guided by constructivist and socio-constructivist principles, supported by ethical safeguards and ongoing teacher development.

4. Applications of ChatGPT in Physics Experimentation

Physics experiments are crucial for building scientific literacy, inquiry skills, and conceptual understanding. However, teachers often face challenges in planning, executing, and evaluating experiments due to limited resources, time, or confidence. ChatGPT offers multifaceted support throughout the experimental process, including design, hypothesis formation, data analysis, and reflection.

Recent classroom studies indicate that AI is transforming lab practices. For example, ChatGPT has been used to organize smartphone-based experiments and act as a conversational partner during hands-on activities [17]. Sirisathitkul [17] found that integrating ChatGPT with smartphone-based physics experiments improved students' inquiry and troubleshooting skills, demonstrating that AI can enhance real-world experimental scenarios.

In the planning phase, ChatGPT can recommend experimental setups, provide step-by-step instructions, and suggest variations suited to different complexity levels. Kotsis [4] showed that primary teachers benefit from ChatGPT's ability to present experiments in structured, adaptable formats, reducing preparation time and helping integrate labs into regular instruction. Kotsis [3] emphasized that ChatGPT makes hands-on activities more accessible to teachers who might otherwise avoid experiments due to inexperience or low confidence.

For hypothesis generation, ChatGPT can prompt students with guiding questions (e.g., "What would happen if we change this variable?") or offer example hypotheses for evaluation. This scaffolding supports engagement in scientific practices while reducing the anxiety associated with open-ended inquiry. Santos [14] and Steinert *et al.* [15] found that large language models promote reflective reasoning and critical thinking, positioning AI as a dialogic tool rather than an answer key.

During experiments, ChatGPT can serve as an on-demand guide. Students can ask about procedures, safety, or unexpected results, receiving immediate feedback that helps prevent misconceptions and keep the activity moving forward. Latif *et al.* [2] demonstrated that AI assistants can act as engaging lab partners, answering technical questions and prompting students to reflect on observations. Kotsis [5] also noted ChatGPT's effectiveness in explaining procedures, suggesting variable adjustments, and maintaining student engagement.

ChatGPT can also generate instructional and reflective resources, such as worksheets that help students record observations, collect data, and analyze results. Kotsis [6] showed that such tools increase student autonomy and support teachers in monitoring progress. Worksheets can be customized for different age groups and ability levels, facilitating differentiation.

Finally, ChatGPT aids in data interpretation and conceptual integration. After experiments, it can help students make sense of results, connect findings to theory, and reflect on discrepancies between predictions and outcomes. This aligns with socio-constructivist approaches that treat dialogue and reflection as essential to knowledge building [7]. By encouraging students to articulate their reasoning, ChatGPT also promotes metacognitive awareness and conceptual change [3, 10].

Despite these benefits, ChatGPT requires careful teacher oversight. Educators must evaluate the feasibility and safety of AI-suggested experiments, and students should be taught to critically assess AI-generated hypotheses or interpretations. ChatGPT is a collaborator in exploration—not a replacement for pedagogical expertise or student agency.

In summary, ChatGPT supports all stages of the experimental cycle—planning, hypothesis formation, execution, reflection, and analysis. It helps make experimental learning more accessible and profound by preparing teachers, engaging students, guiding procedures, providing resources, and supporting conceptual integration. Used strategically, it can make lab experiences more inclusive, dialogic, and effective in building scientific literacy.

4.1 Supporting Diverse Learners with ChatGPT in Physics Experiments

Diverse student backgrounds, prior knowledge, and learning preferences have long posed challenges for physics instruction. Experiments, while essential, can exacerbate inequities if students lack conceptual foundations, language skills, or procedural understanding. Teachers must differentiate instruction and support individual needs while managing whole-class dynamics—a demanding task. ChatGPT can help address issues of access, inclusivity, and personalized support, making physics experiments more equitable and engaging for all learners.

One key advantage is ChatGPT's ability to provide adaptive explanations and scaffolding. It can present physics concepts in various formats and levels of complexity, suited to students' current understanding. Kotsis [5] noted that ChatGPT can serve as a teaching assistant, offering alternative explanations, clarifying terminology, and providing structured reasoning tailored to different learners. This ensures that experimentation promotes meaningful engagement rather than rote activity.

ChatGPT also supports linguistic accessibility. In multilingual classrooms, students may struggle with technical scientific language. ChatGPT can translate terms, give simplified explanations, or produce bilingual worksheets. Kotsis [6] showed how ChatGPT-generated worksheets can be tailored to students with varying language needs, enhancing inclusivity—especially where teachers lack resources to create customized materials. Alarbi *et al.* [18] found that AI-supported scaffolding in high school physics significantly improved student achievement, particularly among lower-performing students, underscoring AI's potential to promote equity in diverse or resource-limited settings.

For students with low prior knowledge or confidence, ChatGPT offers timely, non-judgmental answers to questions, reducing anxiety around inquiry-based tasks. Santos [14] and Steinert *et al.* [15] observed that AI feedback systems encourage intellectual risk-taking, hypothesis formation, and critical thinking without fear of embarrassment. This creates a supportive environment where less confident students can participate actively rather than disengage.

ChatGPT can also support learners with special educational needs or disabilities. While not a replacement for assistive technologies, it can complement them by providing verbal explanations, step-by-step guides, or reformatted instructions. Text-based prompts can be adapted for screen readers, and procedures can be simplified for students with cognitive impairments. These applications align with research advocating AI to enhance accessibility and personalized learning in STEM [10, 11].

Additionally, ChatGPT offers enrichment for advanced learners. These students can use it to explore extended inquiries, design alternative experiments, or simulate scenarios beyond classroom resources. This provides challenge without increasing teacher workload. Kotsis [3] showed that such flexibility helps keep advanced learners engaged while ensuring those needing support are not left behind. Thus, ChatGPT can help balance classroom diversity by supporting both struggling and high-achieving students.

However, supporting diverse learners with ChatGPT requires careful mediation. Chen *et al.* [8] and Cai *et al.* [9] warn that AI-generated explanations may be inaccurate, posing risks for vulnerable learners who might accept misconceptions uncritically. Teacher supervision is essential to ensure ChatGPT remains a supportive tool, not an unchecked authority. Equity also demands that all students have access to the necessary technology, highlighting the importance of infrastructure and teacher training to avoid new digital divides.

In conclusion, ChatGPT offers significant potential to support diverse learners in physics experiments through personalized explanations, multilingual resources, confidence-building scaffolding, and advanced enrichment. When integrated into inclusive pedagogy with teacher facilitation, it can help make experimental physics more accessible and empowering for all students.

4.2 Teacher Professional Development and ChatGPT in Physics Education

The integration of AI into physics education affects not only students but also teachers, whose professional growth is key to effective classroom practice. Physics teachers are expected to design and implement inquiry-based learning that fosters critical thinking and experimental engagement, yet many feel underprepared. Time constraints, limited resources, and rapid technological change add to the challenge. ChatGPT can serve as a valuable tool for teacher professional development, supporting lesson planning, pedagogical innovation, and reflective practice.

One major contribution is reducing the cognitive and logistical load of lesson planning. Teachers must align curriculum goals with practical activities while meeting diverse learner needs. Kotsis [4] showed how ChatGPT can generate structured outlines for physics experiments, including variants adaptable to different grade levels or resources. This saves preparation time and lets teachers focus on pedagogical aspects like facilitating inquiry, reflection, and misconception remediation. Kotsis [6] demonstrated that ChatGPT can produce experiment worksheets that are easily integrated into lessons, reducing resource development burdens.

ChatGPT also builds teacher confidence in experimental instruction. Many teachers, especially at the primary level, hesitate to conduct experiments due to uncertainty about safety, troubleshooting, or instructional sequencing. ChatGPT serves as a virtual assistant, offering procedural guidance and adaptive suggestions during planning, thereby increasing teachers' capacity to organize lab activities. Kotsis [3] found that ChatGPT makes experiments more practicable and encourages previously reluctant teachers to incorporate hands-on activities more regularly.

Beyond planning, ChatGPT supports reflective practice and pedagogical growth. Teachers can use it to explore teaching strategies, generate inquiry prompts, or simulate classroom interactions. Kotsis [5] highlighted its role as a teaching assistant, providing explanations and pedagogical tips tailored to different educational contexts. This aligns with global research indicating that large language models can stimulate professional learning communities, idea generation, and experimentation with new methods [10, 15]. Recent systematic reviews suggest that generative AI can catalyze teacher professional development, especially when used in collaborative design settings rather than in isolation [19]. Deng *et al.* [20] found consistently positive learning outcomes when AI tools supported inquiry and adaptive feedback, though results depended on the degree of teacher mediation and curricular alignment. Interviews with European science teacher educators revealed that preservice teachers are beginning to use ChatGPT in lesson planning, underscoring the need for training in critical evaluation and pedagogical adaptation [21]. Case studies in preservice physics teacher education show ChatGPT supporting lesson preparation and reflection, particularly when teacher educators frame its use within inquiry-based and constructivist approaches [22].

Moreover, ChatGPT supports continuous professional development (CPD) by offering on-demand access to professional learning. Teachers can use it to review content, stay updated on physics education trends, or practice explaining difficult topics. Unlike traditional CPD, which is often limited and sporadic, ChatGPT provides just-in-time support, encouraging self-directed and lifelong learning. This reflects the view that professional development in the digital age should be flexible, personalized, and ongoing [2].

However, using ChatGPT for professional growth presents challenges. Chen *et al.* [8] caution that AI-generated explanations can be inconsistent, requiring teachers to critically evaluate outputs. Overreliance on automated systems for planning or instruction could lead to deskilling. Ethical issues—such as data privacy and AI transparency—must also be addressed to ensure teachers' professional use of AI is trustworthy and secure [11].

In summary, ChatGPT has significant potential to enhance teacher professional development by supporting lesson preparation, resource creation, reflective practice, and continuous learning. It serves as both a practical aid and a catalyst for pedagogical innovation, helping teachers integrate experiments more effectively into physics education. To realize this potential, its use must be grounded in critical engagement, ethical responsibility, and a commitment to preserving—not replacing—teacher expertise.

4.3 Ethical Considerations in Using ChatGPT for Physics Experiments

While ChatGPT offers substantial educational benefits, its classroom use raises important ethical concerns. Issues of accuracy, bias, transparency, data privacy, and overreliance are particularly relevant in physics experiments, where student safety, conceptual understanding, and scientific reasoning depend on reliable guidance and teacher intervention.

A primary concern is the accuracy and reliability of AI-generated content. Although ChatGPT can provide detailed explanations and procedures, it may produce plausible but incorrect responses. In physics, where misconceptions are common, erroneous AI outputs could reinforce misunderstandings rather than support conceptual change. Teachers must therefore verify AI-generated content before using it with students.

Bias and equity are also significant issues. Language models trained on large datasets may reflect cultural, linguistic, or gender biases, potentially perpetuating systemic inequities in science education. To promote inclusive learning, ChatGPT's outputs must be carefully monitored to ensure they are culturally responsive and do not marginalize certain learner groups.

Data privacy and security are critical. Interactions with ChatGPT involve input from students and teachers, raising concerns about data access and storage. Protecting student privacy is a legal and ethical imperative, especially since minors may not fully understand the implications of data sharing. Strong institutional safeguards are needed to ensure compliance with privacy regulations and maintain trust in AI technologies [23].

The risk of overreliance is another key consideration. If teachers depend too heavily on ChatGPT for lesson design or explanations, their professional skills may diminish. Similarly, students who turn to AI for quick answers may fail to develop essential inquiry and reasoning skills. Ethically, ChatGPT should be viewed as a supplementary resource, not a replacement for teacher expertise or student effort.

To mitigate these risks, responsible integration should be guided by three interrelated frameworks. First, students must develop AI literacy. They should be taught to view ChatGPT as a conversational partner in exploration—not an infallible authority—and to critically evaluate AI outputs against empirical evidence or trusted sources. Integrating AI literacy into scientific literacy supports socio-constructivist approaches to experimentation.

Second, teachers need professional development to critically assess AI-generated content, integrate it into curricula, and facilitate its use in classrooms. Training should focus on validating the safety and feasibility of AI-suggested experiments, designing hybrid lessons that preserve hands-on inquiry, and addressing ethical dilemmas like bias and overreliance. Collaborative learning communities can help teachers share experiences and build confidence in using ChatGPT responsibly.

Third, institutional safeguards are essential. Schools and policymakers must develop clear guidelines for AI use, ensure compliance with data protection laws (e.g., GDPR), and guarantee equitable access to AI-enhanced learning. Without such measures, ChatGPT could widen digital divides. Oversight mechanisms—such as ethics committees and pedagogical reviews—can help ensure AI applications are transparent, equitable, and aligned with educational goals.

These institutional efforts connect with international policy frameworks. UNESCO's 2023 guidance on generative AI in education emphasizes human-centered, transparent, and equitable integration, including specific recommendations for teacher training, curriculum implementation, and governance [24]. The OECD's developing AI principles and digital education outlook stress fairness, accountability, and student safety as essential protections [25]. Aligning classroom practices with these global standards strengthens institutional safeguards and situates physics education within broader discussions on AI ethics and governance.

In conclusion, the ethical integration of ChatGPT into experimental physics teaching requires a multifaceted approach: developing students' critical AI literacy, supporting teachers through professional development, and implementing institutional measures to ensure transparency and equity. With these foundations, ChatGPT can serve as a responsible educational partner—promoting inquiry, supporting diversity, and enhancing the teaching and learning of physics experiments without compromising educational integrity.

5. Conclusion

The integration of ChatGPT into physics education offers transformative potential to address persistent pedagogical gaps, particularly in experimentation. Physics experiments are essential for building inquiry skills, conceptual understanding, and scientific literacy, yet their implementation is often hindered by resource limitations, teacher workload, and diverse learner needs. This article has shown how ChatGPT can support all stages of the experimental process—from planning and hypothesis formation to execution, feedback, and data analysis.

Effective and ethical use of ChatGPT requires a multi-level approach. Students must develop AI literacy to engage critically with AI-generated content, viewing ChatGPT as a dialogic partner in inquiry rather than an absolute authority. Teachers need targeted professional development and collaborative learning communities to build the confidence and skills to integrate ChatGPT innovatively and responsibly. Institutions must establish clear policies, data protections, and equitable access to prevent misuse, protect student rights, and ensure AI reduces rather than reinforces educational disparities.

Together, these frameworks emphasize that ChatGPT's value lies not in replacing human agency but in enhancing the teaching and learning of physics experiments. When integrated into constructivist and socio-constructivist pedagogies, facilitated critically by teachers, and supported by institutional safeguards, ChatGPT can make experimental physics education more engaging, inclusive, and future-ready. This requires policymakers to develop ethical guidelines and infrastructure for equitable access; teacher educators to innovate in professional development; and researchers to investigate AI's long-term impact on inquiry, identity, and science education culture.

By aligning student AI literacy, teacher expertise, and institutional accountability, ChatGPT can help advance scientific reasoning and prepare learners for a world where AI is integral to scientific practice and education.

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