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Assignment Wars: Humans with AI — Balancing Integrity, Critical Thinking, and Innovation in Higher Education

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ABSTRACT - The rapid emergence of generative artificial intelligence (AI) tools such as ChatGPT is reshaping higher education, particularly in assessment design. This mixed-methods case study investigates AI-mediated assignments in undergraduate thermodynamics at Universiti Malaysia Sabah (UMS), with comparative pedagogical insights drawn from collaborative academic discussions with partner institutions in Kazakhstan. The "Assignment Wars: Human vs. AI" activity engaged 45 students (n = 45) in critically evaluating AI-generated responses, identifying inaccuracies, and reconstructing disciplinary knowledge. Data were collected through student submissions, course outcome mappings, and reflective feedback. Thematic analysis revealed four key findings: enhanced conceptual understanding, improved critical thinking, increased awareness of factual verification, and strengthened metacognitive reflection. However, students also reported cognitive overload, time demands for verification, and concerns related to academic integrity. Comparative insights from Kazakhstan indicated similar opportunities in promoting critical evaluation skills, alongside shared concerns regarding AI dependency and assessment fairness. The study contributes theoretically by integrating constructivism, critical pedagogy, and the epistemology of error into AI-mediated learning, and practically by proposing a "Humans with AI" assessment model for responsible AI integration in physics education.

INTRODUCTION

The rapid advancement of generative artificial intelligence (AI) tools such as ChatGPT, Bard, and Claude has significantly reshaped higher education. These technologies offer opportunities for personalised learning, adaptive feedback, and enhanced student engagement (Holmes, et al., 2019; UNESCO, 2023). However, growing concerns have emerged regarding academic integrity, superficial learning, and students' overreliance on automated outputs (Luckin et al., 2023). While generative AI can support learning, it may also encourage students to prioritise answers over reasoning, potentially weakening conceptual understanding and critical thinking. These challenges are particularly relevant in physics education, where deep conceptual understanding is essential. Thermodynamics, in particular, remains one of the most abstract and mathematically demanding topics, often leading to misconceptions and shallow learning Sulaiman et al., 2023. Recent studies indicate that students frequently accept AI-generated responses without critically evaluating their accuracy, raising concerns about conceptual understanding and disciplinary reasoning (Kasneci et al., 2023; Cotton et al., 2023;

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Susnjak, 2022). This raises concerns about the impact of AI-mediated learning on conceptual understanding and disciplinary reasoning.

Although generative AI adoption in higher education is increasing, several important gaps remain. First, there is still limited empirical evidence on how AI-mediated assignments influence student learning in real classroom settings, particularly in science and engineering disciplines. Second, existing research often focuses on academic integrity risks or technological capabilities rather than examining AI as a pedagogical tool for fostering critical thinking and epistemic learning. Third, although research on generative AI in education is expanding, much of the existing literature originates from Western contexts, with comparatively fewer empirical studies from Southeast Asia and Central Asia, including Malaysia and Kazakhstan. In Malaysia, recent policy directions such as the Malaysia Education Development Plan (2026–2030), national digital initiatives such as MyDIGITAL and the National Artificial Intelligence Roadmap (AI-RMAP 2021–2025) emphasise the integration of digital technologies and AI to enhance teaching, learning, and future workforce readiness. These initiatives highlight Malaysia's growing commitment to AI-enabled education and digital transformation. Similarly, research in Kazakhstan has explored teacher AI literacy and institutional readiness for AI integration (Abdulayeva et al., 2025; Ibrayeva et al., 2025). However, despite these policy developments and emerging studies, classroom-level empirical evidence on AI-mediated assignments, particularly within STEM disciplines such as physics, remains limited in both contexts.

To address these gaps, this study investigates the "Assignment Wars: Humans vs AI" project implemented in an undergraduate thermodynamics course at Universiti Malaysia Sabah, Malaysia. The project required students to critically evaluate AI-generated responses, identify inaccuracies, and reconstruct disciplinary knowledge. Unlike prior studies that primarily examine AI as a tool or risk, this study positions AI as a catalyst for epistemic engagement grounded in constructivism, critical pedagogy, pragmatism, connectivism, and the epistemology of error.

This study is guided by the following research questions:

RQ1: How do AI-mediated assignments influence students' conceptual understanding in thermodynamics?
RQ2: How do students critically evaluate AI-generated responses?
RQ3: What opportunities and challenges emerge from AI-mediated assignments in physics education?
RQ4: What comparative pedagogical insights emerge from Malaysia and Kazakhstan contexts?

This study contributes to the literature in three ways. First, it provides empirical evidence from a Southeast Asian context, addressing regional gaps in AI-in-education research. Second, it integrates multiple educational theories to explain AI-mediated learning. Third, it proposes a "Humans with AI" pedagogical model that promotes critical thinking, academic integrity, and responsible AI use in physics education. By examining AI-mediated assignments in thermodynamics education, this study contributes to ongoing discussions on responsible AI integration and assessment innovation in higher education.

LITERATURE REVIEW

The integration of generative artificial intelligence (AI) in higher education has generated growing scholarly interest, particularly regarding its influence on learning, assessment, and academic integrity. However, existing literature remains fragmented, often descriptive, and insufficiently connected to disciplinary pedagogy. To address these limitations, this review is organised into four thematic areas: (1) AI for learning, (2) AI and academic integrity, (3) AI in physics education, and (4) theoretical grounding. This thematic structure enables critical synthesis and highlights gaps addressed by the present study.

AI for Learning and Student Engagement

Generative AI has been widely recognised for its potential to enhance learning through personalisation, adaptive feedback, and scaffolded learning experiences. Holmes et al. (2019) and UNESCO (2023) argue that AI technologies can support differentiated instruction by adapting learning pathways to

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individual student needs. These capabilities are particularly beneficial for students encountering abstract or technically demanding concepts. Similarly, Nguyen and Zhao (2022) demonstrated that AI-based simulations enhance conceptual understanding by allowing learners to explore “what-if” scenarios. Huang (2025) further reported that constructivist AI-based assignments improved reflective learning and student engagement. These findings suggest that AI can function as a cognitive scaffold that supports deeper learning when integrated into pedagogical design. Additionally, the integration of digital technologies has been shown to enhance student engagement, collaborative learning, and conceptual understanding in STEM education (Sedi & Mazlan, 2022).

However, contradictions remain. While AI can support personalised learning, some studies caution that excessive reliance on AI may reduce student autonomy and critical engagement (Luckin et al., 2023). Moreover, most AI learning studies focus on general education contexts rather than discipline-specific pedagogy. As a result, limited evidence exists regarding how AI-mediated assignments function within conceptually demanding disciplines such as physics. These limitations directly relate to RQ1 and RQ2**,** which examine how AI-mediated assignments influence conceptual understanding and critical evaluation in thermodynamics.

AI, Academic Integrity, and Superficial Learning

The literature consistently highlights risks associated with generative AI, particularly concerning academic integrity and fairness. Bittle and El-Gayar (2025) reported that institutions remain underprepared for AI-assisted plagiarism, while detection tools struggle to keep pace with rapidly evolving technologies. Similarly, Luckin et al. (2023) warned that AI may exacerbate inequalities and encourage passive learning if students rely uncritically on generated outputs. Student perception studies further reveal tensions between AI utility and reliability. Research involving Malaysian students found that learners valued AI for efficiency but expressed concerns about accuracy and verification effort (Mat Yusoff et al., 2025). International research indicates that AI-generated errors and hallucinations may confuse students and increase cognitive load, particularly when learners rely on AI outputs without verification (Kasneci et al., 2023; Rudolph et al., 2023; Mollick & Mollick, 2024).

These findings highlight a critical contradiction: AI can simultaneously enhance learning and undermine academic integrity. However, most studies focus on risks rather than exploring pedagogical designs that mitigate these concerns. Few studies examine assignments specifically designed to encourage students to critique AI-generated content. This gap informs RQ3, which investigates the opportunities and challenges of AI-mediated assignments.

AI in Physics Education and Thermodynamics Learning

The application of AI in physics education remains underexplored compared to general AI-in-education research. Physics education research highlights that thermodynamics concepts are particularly challenging due to their abstract nature and reliance on conceptual reasoning (Sulaiman et al., 2023). However, recent studies in Malaysian physics education also indicate that AI-based learning tools can enhance conceptual understanding and student engagement in abstract topics (Noorul Aliya et al., 2024). Traditional teaching approaches often rely on repetitive problem-solving, which may not adequately address misconceptions. AI offers opportunities to generate alternative explanations, simulations, and worked examples that support conceptual learning. However, reliance on AI may also reduce productive struggle, which is essential for deep learning in physics (Chi, 2009; Meltzer, 2015). This creates a pedagogical tension: while AI can enhance understanding, it may also bypass cognitive processes necessary for conceptual mastery.

Furthermore, existing AI-in-physics studies remain limited, particularly in classroom-based implementations. Most research focuses on simulations or computational tools rather than generative AI assignments. Additionally, empirical studies from Southeast Asia and Central Asia remain scarce. These limitations highlight the need for discipline-specific research, particularly within thermodynamics education. This gap directly informs RQ1 and RQ3.

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Theoretical Grounding of AI-Mediated Learning

The integration of AI in education has been examined through multiple theoretical perspectives. Constructivism emphasises active knowledge construction, where learners critique and refine information (Piaget, 1970; Vygotsky, 1978). AI-mediated assignments align with this approach by encouraging students to validate generated outputs. Critical pedagogy (Freire, 1970) further emphasises questioning authority, including technological authority. In AI-mediated learning, students must critically evaluate machine-generated knowledge rather than accept it passively. Pragmatism (Dewey, 1938) highlights real-world relevance, suggesting that AI integration prepares students for digital environments. Connectivism (Siemens, 2005; Downes, 2008) conceptualises learning as distributed across networks of humans and technologies. Finally, the epistemology of error (Bachelard, 1938; Popper, 1959) reframes AI inaccuracies as learning opportunities. This perspective is particularly relevant to AI-generated content, which often contains errors that students must detect and correct.
However, few studies integrate these frameworks into a unified pedagogical model. Most theoretical discussions remain conceptual rather than empirically tested. This limitation informs the present study's theoretical integration and supports RQ2 and RQ3.

Synthesis and Research Gap

The literature reveals several key contradictions and gaps. First, while AI enhances personalisation and engagement, it also risks superficial learning and academic integrity concerns. Second, although AI research is expanding, discipline-specific studies in physics education remain limited. Third, most studies examine AI as a technological tool rather than as a pedagogical strategy grounded in educational theory. Finally, empirical research from Southeast Asia and Central Asia remains underrepresented.

Therefore, what remains unknown is how AI-mediated assignments influence conceptual understanding, critical thinking, and academic integrity in physics education within real classroom contexts. This study addresses these gaps by examining the "Assignment Wars: Humans vs AI" project in thermodynamics education, integrating theoretical frameworks and empirical student feedback. This literature synthesis directly informs the study's research questions and establishes the need for empirical investigation.

THEORETICAL FRAMEWORK

This study adopts an integrated theoretical framework to examine the pedagogical implications of AI-mediated assignments in physics education. Rather than treating theoretical perspectives independently, this study synthesises constructivism, critical pedagogy, pragmatism, connectivism, and the epistemology of error into a unified framework guiding assignment design, data analysis, and interpretation.

Generative AI introduces a new learning environment where students interact not only with instructors and peers but also with machine-generated knowledge. Understanding this learning dynamic requires multiple theoretical perspectives that collectively explain how students construct knowledge, critically evaluate information, and develop disciplinary understanding.

Constructivism provides the foundational perspective for this study. According to constructivist theory, learners actively construct knowledge through interaction, reflection, and conceptual restructuring (Piaget, 1970; Vygotsky, 1978). In this study, students were required to evaluate AI-generated responses, identify inaccuracies, and reconstruct disciplinary knowledge. This process aligns with constructivist learning principles, where knowledge is actively constructed rather than passively received.

Critical pedagogy further strengthens this framework by emphasising the importance of questioning authority and knowledge sources (Freire, 1970). In AI-mediated learning, generative AI represents a new form of epistemic authority. Students must therefore critically evaluate AI-generated responses instead of accepting them uncritically. This perspective informed the design of the "Assignment Wars: Humans vs AI" project, where students actively challenged AI-generated content.

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Pragmatism also informs this study by emphasising learning through real-world experiences (Dewey, 1938). AI technologies are increasingly embedded in professional environments, and integrating AI into coursework prepares students for real-world technological contexts. This pragmatic perspective guided the assignment design, ensuring that students developed practical skills in evaluating AI-generated information.

Connectivism further extends the framework by conceptualising learning as distributed across networks of humans and technologies (Siemens, 2005; Downes, 2008). In AI-mediated learning environments, students interact with digital networks, AI tools, and human knowledge sources simultaneously. This perspective informs the study's analysis of how students navigate multiple knowledge sources.

Finally, the epistemology of error provides a critical dimension to the framework. Bachelard (1938) and Popper (1959) emphasise that errors play an essential role in knowledge development. In generative AI environments, inaccuracies in AI-generated responses become learning opportunities. This perspective informed the assignment design, where students identified and corrected AI-generated errors.

CONCEPTUAL FRAMEWORK INTEGRATION

These theoretical perspectives were integrated into a unified conceptual framework guiding this study. The framework positions generative AI as a learning catalyst that promotes engagement, critical evaluation, and knowledge reconstruction. The theoretical integration informs three key aspects of the study: i. *Assignment Design* i.e., Constructivism (knowledge reconstruction activities); Critical Pedagogy (challenging AI authority); Pragmatism (real-world AI application); Connectivism (multiple knowledge sources); and Epistemology of Error (error identification and correction); ii. *Data Analysis*, i.e., student reflections analysed for knowledge construction, critical evaluation patterns examined, engagement and learning processes identified; and iii. *Interpretation*, i.e., learning outcomes interpreted through integrated theoretical lens, AI-mediated learning conceptualised as epistemic engagement

Figure 1 illustrates an integrated theoretical framework for AI-mediated learning, mapping the conceptual flow from a Generative AI assignment to deep learning outcomes. The model aligns diverse pedagogical theories - Constructivism, Pragmatism, Connectivism, and Critical Pedagogy/Epistemology of Error—with specific stages in the learning process to conceptualise AI-mediated learning as epistemic engagement.

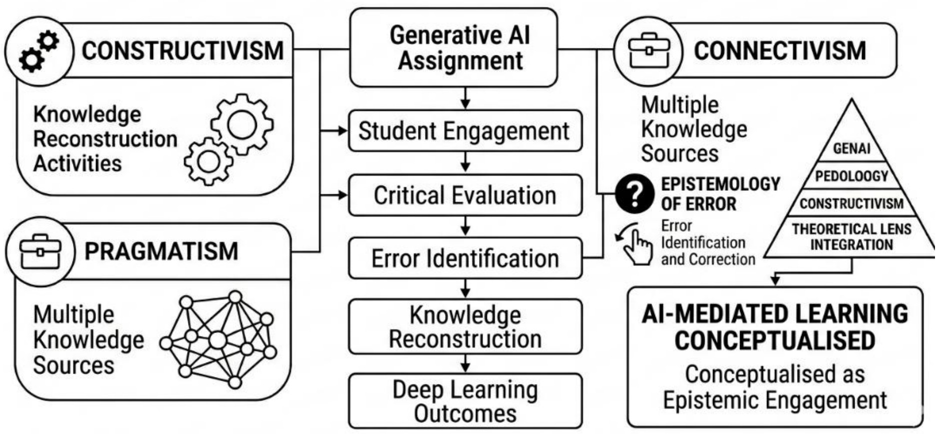

Figure 1. Integrated Theoretical Framework for AI-Mediated Learning

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METHODOLOGY

Research Design

This study employed a qualitative-dominant mixed-methods design (Creswell & Plano Clark, 2018) to investigate the pedagogical impact of generative artificial intelligence (AI)-mediated assignments in undergraduate thermodynamics at Universiti Malaysia Sabah (UMS). The case study approach was selected because it enables in-depth exploration of learning processes within a real classroom context and aligns with the exploratory nature of AI-mediated pedagogical innovation.

The study focused on the "Assignment Wars: Humans with AI" project implemented during Semester 1, 2024/2025 within the Industrial Physics programme. The Malaysian cohort constituted the primary empirical dataset, whilst Kazakhstan insights were derived from collaborative academic discussions and contextual analysis, rather than empirical student data. Therefore, Kazakhstan data are treated as contextual pedagogical perspectives, not comparative empirical findings. The mixed-methods design combined: i. Qualitative data: student reflections, assignment artefacts, and learning outputs; and ii. Quantitative data: Course Learning Outcome (CLO) achievement comparisons across cohorts. This design enabled triangulation of findings and strengthened validity.

Participants and Sampling

Participants consisted of 45 undergraduate students (n=45) enrolled in a thermodynamics course within the Industrial Physics programme at Universiti Malaysia Sabah. A purposive sampling strategy was employed, as the study focused on students enrolled in a course where AI-mediated assignments were implemented.

Students were divided into 11 collaborative teams, each tasked with completing the AI-mediated assignment. Participants had varying levels of familiarity with generative AI tools, reflecting authentic classroom diversity. Ethical approval was obtained through institutional procedures. Students provided informed consent, and all responses were anonymised.

Assignment Design

The "Assignment Wars: Humans vs AI" project required students to:

1. Generate responses using AI tools (e.g., ChatGPT)
2. Critically evaluate AI-generated outputs
3. Identify inaccuracies and conceptual errors
4. Reconstruct disciplinary knowledge
5. Present findings using digital platforms
6. Submit reflective commentaries

This structured approach aligns with constructivist and critical pedagogy principles.

Data Collection

Data were collected from three sources:

i. Assignment Artefacts: - Student outputs from: iTEL (Moodle platform), MTeam, SWAY, YouTube. These artefacts demonstrated knowledge reconstruction and critical evaluation.

ii. Course Outcome Mapping: Student performance was measured using: CLO1 (Thermodynamics knowledge); PLO1 (Disciplinary understanding)

iii. Comparative cohort data included:

- 2022/2023 (Traditional assignment)
- 2023/2024 (Traditional assignment)

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- 2024/2025 (AI-mediated assignment)

iv. Student Reflective Feedback. Students submitted reflective commentaries on:

- Conceptual understanding
- AI reliability
- Learning experience
- Challenges

Data Analysis

i. Malaysia Contextual Analysis

Qualitative Analysis

Qualitative data were analysed using **thematic analysis** following Braun and Clarke (2006), i.e., **Step 1:** Familiarisation with data; **Step 2:** Initial coding; **Step 3:** Theme development; **Step 4:** Theme review; **Step 5:** Theme definition; **Step 6:** Reporting

Table 1. shows the coding framework guided by theoretical constructs

Code Category	Description
Conceptual Understanding	Improved thermodynamics comprehension
Critical Thinking	Evaluation of AI-generated responses
Error Detection	Identification of AI inaccuracies
Knowledge Reconstruction	Correction and synthesis
Cognitive Load	Time and mental effort
Academic Integrity	Concerns about fairness

Reliability and Validity

To ensure reliability: Inter-rater reliability, coding reviewed by two academic colleagues; Peer debriefing, coding discussed and refined; and Triangulation, multiple data sources used; and Audit trail, coding decisions documented

QUANTITATIVE ANALYSIS

Quantitative analysis included Cohort comparison (2022–2025), Mean score comparison and Percentage improvement analysis. This strengthened the quantitative analysis beyond descriptive trends.

i. Kazakhstan Contextual Analysis

Kazakhstan insights were derived from, i. Academic collaboration discussions, ii. Institutional observations and Policy context comparison. No empirical student data were collected from Kazakhstan. Therefore, Kazakhstan findings are presented as contextual pedagogical insights, not comparative empirical analysis. This clarification addresses concerns regarding empirical validity. Whilst for validity and reliability, to ensure methodological rigor, data triangulation, peer review, reflexive analysis and transparent coding framework.

LIMITATION

This study has several limitations that should be acknowledged. First, the research was conducted within a single cohort of undergraduate students (n= 45) in a thermodynamics course at Universiti Malaysia Sabah, which may limit the generalisability of the findings to other disciplines, institutions, or educational contexts. Second, the relatively small sample size restricts the strength of quantitative comparisons and limits inferential statistical analysis. Third, the study relied partly on student self-reported reflections, which may introduce response bias, although this was mitigated through

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triangulation with assignment artefacts and course outcome data. Additionally, the Kazakhstan component was based on contextual academic discussions rather than empirical student data; therefore, these insights should be interpreted as exploratory rather than comparative findings. Finally, the study focused on short-term learning outcomes, and future longitudinal research is needed to examine the sustained impact of AI-mediated assignments on conceptual understanding, critical thinking, and academic integrity.

FINDINGS

This section presents findings from the *Assignment Wars: Humans with AI* project based on student assignment artefacts, reflective feedback, and course outcome achievement data. The findings are organised into three themes: (1) enhanced epistemic engagement and conceptual understanding, (2) cognitive and pedagogical challenges, and (3) evidence of course outcome achievement.

Enhanced Epistemic Engagement and Conceptual Understanding

Analysis of student reflections and assignment artefacts indicates that AI-mediated assignments enhanced students' epistemic engagement and conceptual understanding in thermodynamics. Students demonstrated increased attentiveness to factual accuracy, conceptual reasoning, and disciplinary terminology. This suggests that the requirement to verify AI-generated outputs encouraged active knowledge construction rather than passive information consumption. For example, one student noted that the assignment required greater care in verifying conceptual explanations, which improved understanding of thermodynamics concepts. Another student highlighted that identifying inaccuracies in AI-generated responses helped develop critical awareness of knowledge reliability. These reflections indicate that students adopted a more evaluative stance toward information sources, consistent with constructivist learning principles. This shift toward critical evaluation reflects epistemic engagement, where learners actively interrogate knowledge rather than accept information uncritically. Furthermore, students developed disciplinary literacy by using accurate terminology and cross-checking sources such as textbooks and journal articles. This finding aligns with connectivism learning, where students navigate distributed knowledge networks.

Overall, the findings indicate that AI-mediated assignments fostered deeper conceptual engagement by prompting students to evaluate, verify, and reconstruct disciplinary knowledge. This addresses Research Question 1: How do AI-mediated assignments influence students' conceptual understanding in thermodynamics? And Research Question 2: How do students critically evaluate AI-generated responses?

Cognitive and Pedagogical Challenges

Despite the positive outcomes, students also reported cognitive and pedagogical challenges. The most frequently identified challenge was the additional time required to verify AI-generated responses. While this process supported deeper learning, it also increased cognitive load, particularly when AI outputs conflicted with established sources. Students also reported difficulty accessing reliable verification sources, highlighting issues related to digital literacy and access to scholarly materials. These challenges indicate that AI-mediated assignments require additional scaffolding to support effective learning. Furthermore, students expressed concerns about potential overreliance on AI tools. Although the assignment design encouraged critical evaluation, some learners reported the temptation to accept AI outputs without verification. This finding reflects ongoing debates in AI-assisted education regarding the balance between efficiency and conceptual engagement. Concerns about fairness and accessibility were also raised. Students noted that unequal access to AI tools and verification resources may influence learning outcomes. These findings highlight the need for institutional guidelines and equitable access strategies. This addresses Research Question 3: What opportunities and challenges emerge from AI-mediated assignments in physics education?

Evidence of Course Outcome Achievement

Course Learning Outcome (CLO) mapping provided additional evidence of learning outcomes. The CLO1–PLO1 mapping indicates improved performance in the 2024/2025 cohort compared to previous cohorts. These improvements suggest that AI-mediated assignments may support conceptual

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understanding and higher-order thinking. However, these improvements should be interpreted cautiously. Cohort differences, instructional variations, and external factors such as post-pandemic recovery may also influence performance. Therefore, the findings are interpreted as indicative trends rather than causal effects.

The variety of student outputs—including digital presentations, collaborative outputs, and reflective submissions—provided further evidence of knowledge reconstruction and application. These artefacts demonstrated students' ability to synthesise information and communicate conceptual understanding. Reflective feedback also indicated development of higher-order competencies, including critical thinking, information literacy, and epistemic awareness. Students reported improved ability to evaluate credibility and cross-check information sources, suggesting meaningful learning beyond procedural knowledge. Figure 1 shows the course mapping achievement for the latest three academic year. This also addresses Research Question 3: What opportunities and challenges emerge from AI-mediated assignments in physics education?

CLO1-PLO1 Achievement

ACADEMIC YEAR	2022/2023	2023/2024	2024/2025
Percentage	100 %	86.1%	93.3%

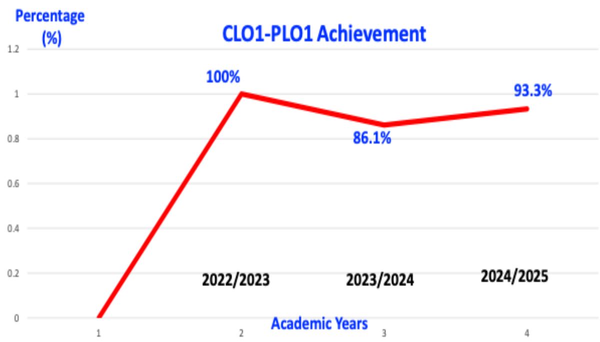

Figure 2. The CLO1-PLO1 Mapping Achievement

Comparative Pedagogical Insights: Malaysia and Kazakhstan

Comparative pedagogical insights emerged from contextual academic discussions and institutional observations between Universiti Malaysia Sabah (Malaysia) and partner universities in Kazakhstan. While empirical data were collected only from the Malaysian cohort, Kazakhstan insights provide valuable contextual perspectives on AI-mediated learning adoption. These insights are therefore interpreted as exploratory pedagogical observations rather than direct empirical comparisons.

Table 2 shows pedagogical opportunities associated with AI-mediated assignments for both Malaysian and Kazakhstan context. Academic discussions indicated that educators in both contexts viewed generative AI as a tool for enhancing critical thinking, conceptual understanding, and student engagement. Like the Malaysian findings, Kazakhstan educators emphasised the potential of AI-generated responses as learning prompts that encourage students to verify information and engage in knowledge reconstruction. This suggests that AI-mediated epistemic engagement may be applicable across diverse educational settings.

Table 2. Comparative Insight for Malaysia and Kazakhstan AI-mediated assignments

Aspect	Malaysia	Kazakhstan	Comparative Insight
Digital readiness	High	Moderate / variable	Infrastructure affects AI adoption
AI familiarity	Moderate–High	Emerging	Training needed
Pedagogical style	Collaborative, reflective	Structured, guided	Complementary approaches

continued

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Opportunities	Critical thinking, epistemic learning	Same	Cross-context relevance
Challenges	Cognitive load, integrity	Same	Shared global issues

However, several contextual differences also emerged. Malaysian students demonstrated relatively higher familiarity with digital learning platforms such as iTEL, SWAY, MTeam, NotebookLM, and collaborative tools, reflecting broader integration of digital learning technologies in Malaysian higher education. In contrast, Kazakhstan institutions highlighted variability in digital infrastructure and AI literacy among students and educators. These differences suggest that successful implementation of AI-mediated assignments may depend on institutional readiness and digital literacy levels.

Additionally, both contexts identified shared pedagogical challenges, including concerns about academic integrity, overreliance on AI, and increased cognitive load associated with verifying AI-generated responses. These concerns align with broader international discussions on responsible AI integration in higher education. Kazakhstan educators similarly emphasised the importance of structured assignment design and clear guidelines to ensure responsible AI use.

Another comparative insight relates to pedagogical culture and instructional practices**.** Malaysian contexts emphasised collaborative learning and reflective assignments, whereas Kazakhstan discussions highlighted structured instructional approaches and teacher-guided learning. These complementary pedagogical approaches suggest opportunities for cross-institutional collaboration, where AI-mediated learning designs may integrate both student-centred and guided instructional strategies.

Overall, the comparative insights suggest that AI-mediated assignments demonstrate potential across both Malaysia and Kazakhstan contexts. However, implementation should consider contextual factors such as digital infrastructure, AI literacy, support system and pedagogical culture. These findings indicate that AI pedagogy is not universally transferable without adaptation, but can be effectively implemented through context-sensitive instructional design. This addresses Research Question 4: What comparative pedagogical insights emerge from Malaysia and Kazakhstan contexts?

These findings indicate that AI-mediated assignments has potential to support deeper learning when carefully designed, while also highlighting the need for structured guidance and equitable access.

DISCUSSION

This study examined the pedagogical implications of AI-mediated assignments in undergraduate thermodynamics through the *Assignment Wars: Humans with AI* project. The findings indicate that generative AI, when integrated into structured learning activities, can promote epistemic engagement, critical thinking, and knowledge reconstruction. Rather than functioning merely as a content generator, AI acted as a catalyst for deeper conceptual learning, where students evaluated, verified, and reconstructed disciplinary knowledge.

Advancing AI Pedagogy Through Epistemic Engagement

A key contribution of this study lies in conceptualising AI-mediated assignments as a form of epistemic engagement. Unlike prior studies that emphasise AI as a tool for efficiency or personalisation, this study demonstrates that AI can potentially stimulate critical inquiry when learners are required to interrogate AI-generated responses. This finding extends constructivist learning theory by positioning AI as an active component in knowledge construction rather than a passive instructional aid. This finding aligns with previous research suggesting that generative AI can enhance student engagement and learning (Kasneci et al., 2023; Mollick & Mollick, 2024). However, this study advances prior work by demonstrating how structured AI-mediated assignments promote **knowledge verification and disciplinary reasoning** within physics education. This discipline-specific evidence contributes to the emerging literature on AI-supported STEM pedagogy, which remains relatively limited.

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AI as a Catalyst for Critical Thinking and Knowledge Reconstruction

The results indicate that requiring students to identify errors in AI-generated responses encouraged deeper conceptual processing. This finding supports the epistemology of error framework, which suggests that learning occurs through confronting misconceptions and reconstructing knowledge. Students did not simply consume AI-generated information but actively evaluated and corrected inaccuracies. This finding contrasts with concerns raised in prior literature that generative AI may promote superficial learning or academic dishonesty (Cotton et al., 2023; Kasneci et al., 2023). Instead, the structured assignment design transformed AI into a pedagogical tool that encouraged metacognitive reflection and conceptual understanding. This suggests that the educational impact of AI depends strongly on instructional design rather than technology alone.

Implications for Physics Education

This study contributes to physics education by demonstrating that AI-mediated assignments can support conceptual learning in thermodynamics, a subject often perceived as abstract and challenging. The use of AI-generated responses created opportunities for students to engage with conceptual explanations, evaluate reasoning, and refine their understanding. This finding extends previous research in physics education, which emphasises active learning and conceptual engagement as key factors in improving student understanding (Freeman et al., 2014). By integrating generative AI into active learning strategies, this study demonstrates a novel approach to enhancing conceptual engagement in physics education. Furthermore, the collaborative nature of the assignment supported peer discussion and knowledge negotiation, reinforcing social constructivist learning processes. This suggests that AI-mediated learning can complement collaborative learning approaches.

Challenges and Pedagogical Considerations

Despite the positive outcomes, the findings also highlight challenges associated with AI-mediated assignments. Students reported increased cognitive load due to the need to verify AI-generated responses. This suggests that while AI can promote deeper learning, it may also require additional scaffolding to support effective knowledge construction.

Concerns regarding academic integrity and fairness were also identified. These findings align with broader concerns in AI-assisted education regarding ethical use and equitable access. Therefore, institutions must develop clear guidelines and provide structured support for AI-integrated learning.

Contribution to Knowledge

This study makes three key contributions. First, it introduces the concept of AI-mediated epistemic engagement as a pedagogical framework for higher education. Second, it provides empirical evidence from physics education, addressing a gap in discipline-specific AI pedagogy research. Third, it demonstrates how AI can support deeper learning when integrated into structured assignments rather than used as a passive tool. These contributions advance current understanding of generative AI in education by shifting the focus from AI as a productivity tool to AI as a catalyst for critical thinking and knowledge construction.

Overall, this study demonstrates that generative AI can enhance learning when embedded within structured pedagogical designs. By encouraging students to evaluate, verify, and reconstruct knowledge, AI-mediated assignments promote epistemic engagement and deeper conceptual understanding. These findings highlight the importance of instructional design in shaping the educational impact of generative AI.

CONCLUSION AND IMPLICATIONS

This study examined the pedagogical implications of AI-mediated assignments in undergraduate thermodynamics through the *Assignment Wars: Humans with AI* project at Universiti Malaysia Sabah. The findings suggest that structured generative AI assignments can promote epistemic engagement, critical evaluation, and knowledge reconstruction. Students demonstrated increased attention to conceptual accuracy, critical thinking, and disciplinary reasoning when required to verify AI-generated

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responses. These outcomes indicate that generative AI, when thoughtfully integrated into instructional design, can potentially support deeper learning processes rather than merely facilitating content generation.

However, these findings should be interpreted within the scope and limitations of the study. The research was conducted within a single cohort of 45 undergraduate students in a specific disciplinary context, which limits the generalisability of the results. Additionally, the improvements observed in course learning outcomes cannot be attributed solely to AI-mediated assignments, as other factors such as cohort differences, instructional variation, and assessment design may also have influenced student performance. Therefore, the findings should be considered indicative rather than conclusive.

Despite these limitations, the study offers important implications for AI pedagogy in higher education particularly for Malaysia and Kazakhstan context. First, the findings suggest that generative AI can be used to foster epistemic engagement when assignments require students to critically evaluate and reconstruct knowledge. Second, structured AI-mediated assignments may help develop higher-order skills such as critical thinking, information literacy, and conceptual reasoning. Third, the study highlights the importance of instructional design in shaping the educational value of generative AI, particularly in complex subjects such as thermodynamics.

Future research should extend this work through more robust methodological designs. Longitudinal studies are needed to examine the sustained impact of AI-mediated assignments on conceptual understanding, learning behaviour, and academic integrity over time. Experimental studies comparing traditional assignments with AI-mediated approaches would also help establish causal relationships. Additionally, cross-disciplinary studies across STEM and non-STEM subjects could explore the broader applicability of AI-mediated epistemic engagement. Comparative international research involving multiple institutions, including Malaysia and Kazakhstan, would further strengthen cross-cultural understanding of AI-supported pedagogy.

In conclusion, this study provides preliminary evidence that generative AI, when integrated into structured pedagogical designs, can support deeper learning and critical engagement in physics education. While further research is needed to validate and generalise these findings, the results contribute to the growing body of literature on AI-mediated learning and offer practical guidance for educators seeking to integrate generative AI responsibly and effectively.

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AUTHORS CONTRIBUTION

Tien Tien Lee served as the primary supervisor for this research, providing ongoing guidance, critical feedback, and detailed content reviews throughout the dissertation process. His role played an important role in shaping the structure, academic rigor, and overall direction of the study. **Fauziah Sulaiman** contributed by inspiring the research focus and helping to establish the basic research. **Maira Katbayeva** played an important role in checking the formatting and ensuring that documents conform to academic and submission standards. **Sapargali Pazylbek** was responsible for conducting the research, site analysis, literature review, data interpretation, and final drafting of the Paper.

AVAILABILITY OF DATA AND MATERIALS

Data available on request from the authors.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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DECLARATION OF GENERATIVE AI

During the preparation of this work, the author(s) used Quillbot and ChatGPT to enhance the clarity of the writing. After using the Quillbot and ChatGPT, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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