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Article

Reclaiming the Inventor’s Mind in the Age of AI: A Pedagogical Shift from Consuming Recipes to Cultivating Personal Reflection in Physics Education

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Abstract

Physics education traditionally presents the discipline as a collection of established recipes, omitting the personal, a priori reflection central to the historical development of theories. The rise of Generative AI has exposed the fragility of this recipe-based model, as AI can now execute algorithmic problem-solving effortlessly. This theoretical paper argues that this technological disruption is a catalyst for a fundamental reorientation: the physics classroom must be reconceived as a space for structured thinking, where theories are presented as subjective, creative resolutions to problems, a direct reflection of an inventor’s mind. We synthesize historical and philosophical analyses with contemporary physics education research (PER) on student epistemologies, conceptual change, and metacognition to propose a pedagogical framework centered on three pillars: acknowledging subjectivity in theory-building, recognizing multiple equivalent formulations, and leveraging historical narrative. We further introduce AI-assisted classroom strategies designed to implement this shift, positioning AI as a Socratic partner and historical simulator. The paper concludes with a set of testable propositions to guide future empirical research. This work contributes a novel theoretical synthesis that integrates AI into a historically-grounded, reflective pedagogy, aiming to cultivate the *inventor’s mind* and prepare students not merely as consumers of knowledge but as creators of future possibilities.

Keywords: AI; generative artificial intelligence; physics education; physics pedagogy; inventor’s mind

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1. Introduction: The Didactic Paradox of Physics in the Age of AI

It’s seldom overstated to say that a physics classroom is primarily a space for thinking about the world around us in a controlled and organized manner. In essence, all physical theories taught in classrooms are the result of a deep and fruitful thinking process involving imagination and analysis as well as prediction and experimental validation.

The sentiment expressed above encapsulates the very essence of physics as a human endeavor. It is a dynamic process of modeling reality, a dialogue between a curious mind and the natural world. Yet, the moment this living process is distilled into the curriculum of a school, it undergoes a profound transformation. It hardens into what the initial problematic correctly identifies as *a set of pre-established recipes ready to be consumed by students in an already specified fashion*. This is the central didactic paradox

of physics education: we teach the results of revolutionary thinking as if they were self-evident truths, stripping them of the very struggle, imagination, and personal reflection that gave them birth (Arons 1993).

The arrival of Large Language Models (LLMs) and Generative AI has thrown this paradox into sharp relief. If the goal of physics instruction is to train students to correctly apply a recipe such as to plug numbers into $F = ma$ or to solve a Kirchhoff's loop problem, then AI has already surpassed the vast majority of students. It can execute these algorithmic tasks instantly and accurately (Cooper and Tang 2023). This development renders the traditional, transmissionist model not just pedagogically weak, but existentially obsolete. Why spend years training students to do what a machine can do in seconds?

However, this crisis is also a profound opportunity. By making the *recipe* trivial, AI forces us to return to what truly matters: the *inventor's mind*. AI cannot replicate the a priori personal reflection, the historical struggle, or the subjective choice between equivalent formulations that constitutes the heart of scientific thinking. As Holmes and Porayska-Pomsta (2023) notes, the future of education lies not in competing with AI on its own terms, but in leveraging AI to augment uniquely human cognitive skills such as creativity, critical reflection, and personal sense-making.

This paper responds directly to the call embedded in the opening problematic, now viewed through the lens of this technological revolution. We will explore the consequences of presenting physics as a finalized product rather than a process, and propose a viable alternative that integrates AI not as a cheat code, but as a catalyst for deeper thought. We will argue that a physics education worthy of its name must harness AI to recapture the *inventor's mind*, transforming the classroom from a site of passive consumption to an arena of active, structured, and personally meaningful thinking.

2. Methodology and Theoretical Framework

This paper presents a *conceptual analysis* and *theoretical synthesis* (diSessa 2008; Hammer et al. 2005) that draws on three sources: (1) historical and philosophical analyses of scientific practice (e.g., Holton 1973; Nersessian 1995); (2) existing physics education research (PER) on student epistemologies, conceptual change, and metacognition; and (3) emerging scholarship on AI in education. We do not report new empirical data; rather, we integrate these strands to construct a coherent pedagogical framework. The goal is to generate testable propositions that can guide future empirical research, as called for by Cooper and Tang (2023) in their review of AI in physics education.

Our framework builds on established PER findings:

- **Student epistemologies:** Hammer (1995) showed that students who view physics as a coherent system of ideas learn more deeply than those who see it as disconnected facts. Our approach explicitly targets this epistemological stance.
- **Conceptual change:** Posner et al. (1982) emphasized the role of intelligibility, plausibility, and fruitfulness in conceptual change. Historical re-enactment makes new concepts more intelligible by showing their origins.
- **Cognitive frameworks:** Redish (2003) and Etkina et al. (2015) have argued for the importance of helping students build mental models. Our multiple-formulations strategy directly supports this.

By synthesizing these perspectives with the affordances of generative AI, we propose a pedagogical model centered on three theoretical foundations.

3. The Theoretical Foundation: Subjectivity, Multiplicity, and Historical Thinking

The proposed pedagogical shift rests on three interconnected theoretical pillars: the acknowledgment of subjectivity in scientific theory-building, the recognition of the multiple mathematical representations of physical laws, and the deliberate use of historical narrative to humanize the scientific process.

3.1. *The Theory as a Reflection of the Mind*

The traditional view of scientific knowledge is one of progressive objectivity, a gradual peeling away of subjective layers to reveal nature's true structure. However, philosophers and historians of science, such as Gerald Holton, have demonstrated the persistent role of what he calls *themata* a fundamental, often non-testable, presuppositions that guide the work of individual scientists (Holton 1973). For instance, Einstein's relentless pursuit of unified field theory was driven by a deep-seated thema of unity and determinism, a personal commitment that went beyond the available empirical evidence. Similarly, Niels Bohr's principle of complementarity was not a direct reading of experimental data but a philosophical interpretation of the quantum world, reflecting his particular intellectual disposition. In the classroom, this translates to a crucial insight: the laws of physics are not dictations from nature but are human responses to nature's prompts. They are a direct reflection of the mind of the inventor. When a student struggles to understand the wave-particle duality, they are not failing to grasp an objective reality but are grappling with a concept that was itself born from a profound struggle within the minds of Bohr, Heisenberg, and others. Presenting the theory without this struggle is to present a corpse, not a living being.

3.2. *The Principle of Multiple Equivalent Formulations*

A powerful tool for relativizing the curriculum is the explicit acknowledgment that the same physical content can be encoded in different mathematical languages. Classical mechanics provides the most vivid illustration. It is possible to teach the entirety of Newtonian dynamics not only through Newton's laws (vectorial mechanics) but also through the formulations of Lagrange (analytical mechanics) and Hamilton (Hamiltonian mechanics). While Newton's approach focuses on forces as the primary agents of change, Lagrange's method abstracts forces away, focusing instead on energies and generalized coordinates. Hamilton's formulation reimagines the entire theory in terms of a single function and a set of conjugate variables, paving the way for statistical mechanics and quantum theory. Each formulation offers a distinct *cognitive handle* on the same phenomena. In a traditional classroom, the Lagrangian or Hamiltonian approaches are often reserved for advanced students, presented as superior or more sophisticated tools. However, introducing them even in a qualitative or simplified manner at an introductory level can be liberating. It demonstrates that there is no single *correct* way to view mechanics, only more or less useful tools for a given problem. This empowers students to seek the formulation that best aligns with their own developing comprehension, reinforcing the idea that physics is a personal construction of understanding.

3.3. *Learning from History: The Role of A Priori Perspectives*

The *inventors* of physical theories did not work in an intellectual vacuum. They were products of their time, steeped in specific philosophical, religious, and cultural contexts. Galileo's defense of heliocentrism was not merely an empirical argument but a battle against an entrenched Aristotelian worldview that was intertwined with Church doctrine. Kepler's search for the laws of planetary motion was motivated by a mystical belief in a underlying mathematical harmony of the cosmos. To present Kepler's laws as simple empirical summaries of Tycho Brahe's data is to miss the entire motivational engine of his work, namely, his a priori belief in a universe designed according to geometric principles. Nersessian (1995) argues for the importance of *cognitive-historical analysis* in science education, suggesting that by tracing the conceptual development of a scientific idea, we can better understand the cognitive obstacles that students themselves might face. When students learn about the photoelectric effect, they often share the same intuitive realism that led classical physicists to be baffled by Einstein's photon hypothesis. By revisiting this historical confusion, the teacher validates the student's initial intuition and then guides them through the revolutionary conceptual leap that was required to resolve it. This process of historical re-enactment can foster a deeper and more resilient understanding.

4. Case Studies: Breathing Life into the Curriculum

To move from theory to practice, we can examine how specific topics might be taught with a focus on personal reflection and historical struggle.

4.1. Newtonian Mechanics: Beyond Force as a Push

The traditional introduction to Newton's Second Law ($F = ma$) often involves defining force, mass, and acceleration, then solving for unknowns. This approach rarely questions the profound conceptual shift Newton introduced. A more reflective approach would begin by asking students to consider the pre-Newtonian world. What did it mean to explain motion before Newton? Students could explore the impetus theory of Jean Buridan, a 14th-century philosopher, who suggested that a mover imparts an *impetus* to an object, which keeps it moving until it is exhausted. This theory, which resonates with many students' intuitive physics, was a coherent and personal attempt to explain motion. The class could then examine why Galileo's experiments and Kepler's laws strained this framework, setting the stage for Newton's radical synthesis. Newton's achievement was not just in stating $F = ma$, but in redefining the very concepts of force (as a cause of change in motion, not motion itself) and mass (as a measure of inertia). The universal law of gravitation, presented not as a given but as Newton's personal, and to some, disturbing, hypothesis of *action at a distance*, becomes a testament to his intellectual audacity. Students could be challenged to create their own personal synthesis of motion, perhaps by trying to explain the same phenomenon (e.g., a ball rolling down a hill) using impetus theory, Newtonian forces, and then an energy-based (work-energy) perspective, reflecting on the advantages and limitations of each view. Many alternative laws can be presented to the students where force is proportional to velocity or higher derivatives of the velocity. Discriminating successfully between equally plausible laws of mechanics induces within the student a deeper appreciation of why the world is the way it is.

4.2. Electromagnetism: Seeing the Field Through Different Eyes

The concept of a field is notoriously abstract. The standard presentation introduces electric and magnetic fields as mathematical constructs to avoid dealing with action at a distance. However, the historical development reveals two deeply different personal visions: Faraday's and Maxwell's. Michael Faraday, with minimal mathematical training, envisioned lines of force as real, physical entities filling space like tense rubber bands or flowing fluids. He could see them in his mind's eye, and this visual, tactile intuition guided his experimental discoveries. James Clerk Maxwell, a mathematical physicist, translated Faraday's mental images into a set of partial differential equations. While Maxwell's equations are the towering achievement of classical physics, they represent a different cognitive style, that is, a formal, abstract one. An effective classroom strategy would be to juxtapose these two perspectives. Students could first be asked to draw the electric field around a dipole using Faraday's lines of force approach, considering how a test charge would move and how the lines would *push* and *pull*. They could then be introduced to the mathematical formalism of Gauss's law as a precise way of stating that the number of lines emanating from a charge is proportional to the charge itself. This duality between the visual and the analytical demonstrates that the field concept is not a single objective thing but a rich conceptual tool that can be grasped in multiple, equally valid ways.

4.3. Quantum Mechanics: The Ultimate Manifestation of Subjectivity

Quantum mechanics, with its inherent ambiguities, is perhaps the ideal topic for this pedagogical approach. The traditional *shut up and calculate* mantra, while pragmatically useful for solving problems, is intellectually devastating. It robs students of the most profound debates in 20th-century physics. A reflective course on quantum mechanics would not simply present the Schrödinger equation and its solutions. It would be structured around the philosophical struggle to interpret the mathematics. Students would explore Niels Bohr's Copenhagen Interpretation, with its emphasis on complementarity and the necessity of a classical apparatus. They would then encounter the personal rebellion of Einstein, Podolsky, and Rosen, who argued that the wave function could not be a complete description

of reality, driven by their a priori commitment to realism and locality. They would grapple with the many-worlds interpretation of Hugh Everett III, a radically personal and initially ridiculed attempt to solve the measurement problem by eliminating wavefunction collapse altogether (Deutsch 1997). By engaging with these interpretations, students realize that the mathematics does not speak for itself. It must be interpreted. This forces them to reflect on their own metaphysical commitments. Do they prefer a world with a random collapse (Copenhagen), a non-local hidden reality (de Broglie-Bohm), or an infinite number of branching universes (Everett)? Their choice is not about right or wrong, but about what constitutes a satisfying explanation, thus placing them in the same position as the founders of the theory.

4.4. Entropy: A Century of Personal Struggle Across Disciplines

Few concepts in physics illustrate the gap between the historical struggle of invention and the sterile presentation of the classroom better than entropy. In a typical textbook, entropy is often introduced in one of two ways: as a dry, macroscopic state function defined by the Clausius inequality ($\Delta S = \int dQ_{rev}/T$) or as a statistical measure of *disorder* ($S = k \ln W$) that is often misleading and conceptually vague (Lambert 2002). Students are expected to grasp this profound concept within a few class hours, despite the fact that its development spanned generations, from the practical engineering of Sadi Carnot to the abstract statistical mechanics of Ludwig Boltzmann and Josiah Willard Gibbs, and it continues to evolve in modern non-equilibrium thermodynamics. This compressed presentation robs students of the opportunity to see entropy as a concept born from multiple, deeply personal attempts to understand the direction of time and the nature of heat.

The historical journey of entropy is a story of shifting perspectives. Sadi Carnot, an engineer, was concerned with the efficiency of steam engines. His personal, a priori perspective was practical: how much useful work can be extracted from heat? His reflections on the *motors of fire* led to the realization that work is obtained not by consuming caloric, but by its fall from a hot to a cold body, analogous to water falling in a waterfall. This was an engineering view, rooted in analogy and utility. Rudolf Clausius later formalized Carnot's insights, but he was driven by a different need: to reconcile Carnot's principle with the new conservation of energy laws. His personal contribution was to identify a new quantity, which he named entropy from the Greek for *transformation*, that always increases in isolated systems. For Clausius, entropy was a macroscopic, mathematical necessity to codify the irreversibility he observed in nature.

Ludwig Boltzmann, however, saw entropy through an entirely different lens. A staunch atomist, his personal worldview compelled him to seek a mechanical, microscopic foundation for Clausius's macroscopic law. For Boltzmann, entropy was not a fluid or a function, but a measure of the number of microscopic arrangements (Ω) corresponding to a given macroscopic state. His famous grave marker, $S = k \ln W$, is a testament to this deeply personal and, at the time, highly controversial atomistic interpretation. Boltzmann's struggle was not just mathematical; it was philosophical, facing fierce opposition from positivists like Ernst Mach who rejected the very existence of atoms. His tragic end is a somber reminder that the creation of physical theory is a human endeavor with high personal stakes. Finally, Josiah Willard Gibbs, the great American physical chemist, synthesized and extended these views. His geometric and graphical approach to statistical mechanics, using phase space and ensembles, provided yet another formulation where a more abstract and powerful language that unified the macroscopic and microscopic views. Gibbs's perspective was that of a mathematical physicist seeking the most general and elegant framework.

In the classroom, the traditional approach of presenting entropy as a *fait accompli* leaves students confused and alienated. They are expected to seamlessly integrate the engineering, the macroscopic, and the statistical views, a feat that took humanity a century to achieve. A reflective pedagogical approach, by contrast, would lay bare these historical layers, inviting students to construct their own understanding by grappling with each perspective in turn.

A classroom strategy for teaching entropy through the *inventor's mind approach* could unfold over several days, structured as a historical narrative. First, the class is introduced to the *Engineer's Problem*.

Students are presented with the task of a 19th-century engineer: given a source of heat (like a boiler) and a sink (like a cold reservoir), how can we maximize the amount of work we get out of a heat engine? Through thought experiments with idealized engines, guided by Socratic questioning (potentially with AI assistance as described later in Section 6), students can be led to rediscover Carnot's insight: the efficiency depends only on the temperatures, and that in any real process, something is *lost* or *wasted*, even though energy is conserved. This *something* is the precursor to entropy. The emphasis is on the student's personal sense-making of a practical problem.

Second, the class shifts to the *Mathematician's Necessity*. Building on the engineering insights, the teacher introduces Clausius's dilemma: how do we mathematically capture this loss in a way that is compatible with the new principle of energy conservation? The teacher presents Clausius's solution: the quantity $\frac{Q}{T}$, and the realization that for any real cycle, the sum of these quantities is less than zero, leading to the definition of a new state function, entropy. The focus here is on the need for a new concept, not just the formula. Students can be asked to calculate entropy changes for simple reversible and irreversible processes, feeling the mathematical consistency for themselves.

Third, the class enters the *Atomist's Vision*. Here, the teacher introduces Boltzmann's worldview. Through simple coin-flip or dice-rolling analogies (or simple computational simulations), students can explore the idea of microstates and macrostates. They can personally experience that the macrostate of all heads is far less probable than a mixed macrostate, and that systems naturally evolve towards the most probable macrostate. The teacher then reveals Boltzmann's equation as the formalization of this intuition: entropy is a measure of this probability, of the number of ways a state can be realized. The emphasis is on the shift in perspective: from a continuous, macroscopic quantity to a discrete, statistical one.

Finally, students are asked to synthesize. They can be assigned a reflective essay or a dialogue with an AI (simulating Carnot, Clausius, and Boltzmann) in which they must explain what entropy is from each of these three perspectives. The goal is not to find the single correct definition, but to appreciate that each definition reflects a different personal and historical approach to the same deep problem. The student, by the end, is not just a user of the entropy formula, but a participant in the century-long conversation that created it.

This multi-perspective journey through the history of entropy finds a powerful and modern synthesis in the work of Barzi and Fethi (2025). They argue that the persistent difficulty students face with entropy stems from its obscure and ambiguous nature and the lack of a clear, everyday cognitive anchor. To resolve this, they propose a radical reformulation of classical thermodynamics by replacing the concept of entropy entirely with the more intuitive concept of *information stored in a system*. In their framework, the number of microstates Ω is directly linked to the number of bits α needed for a binary encoding ($\Omega = 2^\alpha$). This leads to a redefinition of entropy as $S = \mathcal{R} n_b$, where $n_b = \alpha / N_A$ is the *number of moles of information* (measured in mole-bits or molb), and $\mathcal{R} = k_B N_A \ln 2 \approx 5.76 \text{ J K}^{-1} \text{ molb}^{-1}$ is a modified gas constant representing the energy cost per mole of information. The second law is then restated in terms of the inevitable increase of this stored information in an isolated system. For a student, this reformulation offers exactly what the historical narrative lacks: a tangible, measurable quantity. Instead of grappling with the abstract increase of entropy, they can envision the system's internal information content growing, requiring more binary digits to encode its possible microstates. Such a shift allows the teacher and student to focus more on the physical implications of the laws not on the laws themselves. It also provides a direct answer to the student's plea for a physical picture, transforming entropy from a mysterious function into a concrete count of the system's internal informational complexity. This contemporary reformulation stands as yet another powerful example of a personal, a priori attempt to understand nature, here, by using the clear language of information theory to cut through the conceptual fog surrounding a century-old idea.

As argued by Lambert (2002) in his advocacy for a disorder free definition, this process forces a level of conceptual clarity that rote problem-solving cannot achieve. The gratitude the student feels is

not just for the final answer, but for the generations of thinkers who, through their personal struggles, built the intellectual bridge the student is now invited to cross.

5. The Symbiotic Catalyst: AI as a Partner in Reflective Physics Education

The rise of Generative AI, rather than undermining the need for physics education, provides the most compelling argument yet for abandoning the recipe-based model. If AI can execute the recipes, then the only defensible educational goal is to cultivate the skills AI cannot replicate: personal reflection, creative model-building, historical empathy, and the subjective selection between multiple valid frameworks (Molnár and Kárpáti 2023). This section outlines strategies to integrate AI as a partner in this endeavor.

5.1. AI as a Socratic Partner for Thought Experiments

One of the most powerful uses of AI is as an infinite reservoir of Socratic questions. Traditionally, a teacher's time is limited, and deep, personalized dialogue with every student is impossible. AI can fill this gap. When a student proposes a personal model or an interpretation of a phenomenon, they can engage an AI in a structured dialogue to test the robustness of their idea.

- **Strategy:** After a student develops a personal explanation for, say, why a spaceship needs no fuel to keep moving in deep space (their own law of inertia), ask them to prompt an AI: I am a student who thinks [insert their idea]. Act as a Socratic tutor. Challenge my assumption by asking me probing questions, but do not give me the right answer from Newtonian physics. Help me discover the flaws or strengths in my own reasoning.
- **Pedagogical Goal:** This process forces the student to articulate their a priori perspective clearly. The AI's follow-up questions push them to consider edge cases and contradictions, mirroring the process of peer review and internal reflection that drives scientific progress. The student is not receiving an answer; they are engaging in a reflective dialogue that refines their own thinking.

5.2. AI for Exploring Multiple Equivalent Formulations

The principle of multiple formulations can be brought to life by using AI as a translator between different mathematical or conceptual languages. Students often feel locked into the specific notation their textbook uses. AI can demonstrate that this notation is merely one choice among many.

- **Strategy:** After teaching a concept like simple harmonic motion using Newton's laws, ask students to use an AI to translate the solution. For example: Explain the motion of a mass on a spring using the language of Lagrangian mechanics. Show the Lagrangian, derive the equation of motion, and explain what is conceptually different about this approach compared to using $F = ma$. For advanced students: Now show me the Hamiltonian formulation. What are the conjugate variables here, and what is conserved?
- **Pedagogical Goal:** This demonstrates that physics is not a single story, but a set of parallel narratives. By seeing the same underlying reality described in different mathematical languages, students begin to understand that the language is a tool, not the truth itself. They can then be asked to reflect on which formulation feels most intuitive to them, fostering metacognition about their own cognitive style.

5.3. Simulating Historical Debates and Personalities

AI can be prompted to adopt the persona of historical physicists, allowing students to interview the inventors themselves. This makes the historical struggle visceral and personal.

- **Strategy:** In a unit on special relativity, a student could be tasked with interviewing Henri Poincaré and Albert Einstein separately. They could ask: What did you believe about the ether? Why was your approach to the problems of motion different from Lorentz's? What personal conviction drove your work? The AI, if prompted with sufficient historical context, can generate responses that reflect the known views and personalities of these figures (Bitzenbauer 2023).

- **Pedagogical Goal:** This strategy directly addresses the call to acknowledge that theories are *a direct reflection of the mind of the inventor*. By conversing with Einstein's insistence on principle theories versus Lorentz's constructive approach, the student internalizes the idea that science is a human conversation, not a monologue from a textbook.

5.4. AI as a Critic of Personal Models

The ultimate goal is for students to develop their own tentative understandings. AI can serve as a low-stakes, infinitely patient critic of these personal models.

- **Strategy:** Ask students to write a short essay explaining a physical phenomenon in their own words, using whatever analogies or mental models make sense to them. Then, have them submit this text to an AI with the prompt: Here is a student's personal explanation of [phenomenon]. Identify the implicit assumptions in their model. Where does their analogy break down if we push it to extremes? What would an experiment look like that could test their model against the accepted scientific one?
- **Pedagogical Goal:** This process validates the student's personal effort (the AI is not saying they are *wrong*, but analyzing the structure of their thinking). It also demonstrates the core scientific activity of model criticism and refinement. The student learns that their ideas are valuable, but also that all models have limits.

6. Classroom Strategies for Cultivating the Inventor's Mind

Implementing this vision requires a deliberate shift in classroom practice. The following strategies are designed to foster personal reflection and relativize the curriculum.

6.1. The Historical Re-Enactment Laboratory

Instead of standard verification labs, students can be asked to re-enact historical moments of discovery or confusion. For example, before introducing Ohm's law, provide students with batteries, wires, and various materials (including some that are not Ohmic like a light bulb filament). Ask them to investigate the relationship between the number of batteries (voltage) and the current. They will be forced to create their own models, perhaps a linear model, a model that shows a threshold or a model where things get hot and change. Only after they have presented and debated their own *laws* should the instructor introduce Ohm as one person's particular (and limited) finding. This process, advocated by [Arsalidou \(2019\)](#), models the authentic process of science: pattern recognition, model building, and peer review.

6.2. The Multiple Formulations Problem Set

Rather than always assigning problems in a single format, design problem sets that require students to translate between formulations. For example, after teaching both Newtonian and Lagrangian mechanics, ask students to solve the same simple problem (e.g., the Atwood machine) using both methods. Then, have them write a short reflection on which method felt more intuitive to them and why. This not only reinforces the content but also forces metacognitive reflection on their own cognitive style.

6.3. The Biographical Vignette

Start each major unit not with the equations, but with the person. A 10-minute discussion about who Newton, Faraday, or Einstein was as a person, their quirks, their beliefs, their struggles to humanize the subject. Discuss Faraday's humble beginnings as a bookbinder's apprentice and his lack of formal education. Talk about Einstein's rejection from the ETH Zurich and his years as a patent clerk. This demonstrates that physics is done by people, not demigods, and that their personal journeys were integral to their scientific ones.

6.4. Cultivating A Priori Thinking: The Thought Experiment

Dedicate class time to thought experiments. Before deriving the consequences of special relativity, engage the class in Einstein's own thought experiment: What would I see if I rode alongside a beam of light? Before introducing the ideal gas law, ask students to imagine they are a tiny being inside a box full of moving particles. How would they explain the pressure on the walls? This type of questioning forces students to build a model from the ground up, based on their own reasoning, before being given the *official* answer. This values their personal intuition and treats it as the raw material for scientific thinking.

7. Challenges and Affordances of a Reflective Pedagogy in the AI Era

Adopting this approach is not without its challenges. The most immediate is the pressure of a standardized curriculum. In many educational systems, teachers are judged by their students' performance on high-stakes exams that often reward rote learning and rapid problem-solving. A pedagogy that prioritizes deep reflection and historical narrative may seem like a luxury that cannot be afforded. Furthermore, the integration of AI raises new concerns about academic integrity. If students can ask AI to do their thinking for them, how do we ensure they are developing their own reflective capacity? The answer lies in changing what we assess. If we assess the ability to have a personal, coherent, and critically examined perspective, something AI cannot authentically possess, then using AI as a research assistant or Socratic partner becomes a skill, not a cheat (Cooper and Tang 2023).

Furthermore, this approach demands significantly more from the teacher. It requires a deep understanding of the history and philosophy of physics, not just its mathematical formalism. The teacher must be comfortable with ambiguity, willing to say, **I don't know**, or **There are multiple ways to think about this**. This can be unsettling for teachers accustomed to being the sole authority in the room. However, AI can also assist the teacher here, by helping to generate historical vignettes, design Socratic dialogues, or quickly produce examples of different mathematical formulations.

However, the affordances are profound. This approach has the benefit of relativizing the learning process and abolishing dogmatic thought. When students understand that scientific knowledge is a human construction, they are less likely to be intimidated by it and more likely to engage with it critically. The acceptance and appreciation of the studied theory will be greatly enhanced as feeling the difficulty to formulate an alternative forces gratitude to the inventor. This gratitude is the seed of genuine scientific literacy. It transforms the student from a passive consumer into an active participant in a centuries-old conversation. Research by Hammer (1995) on student epistemologies suggests that when students view physics as a coherent system of ideas that they can make sense of, rather than as disconnected facts and formulas, their learning is deeper and more transferable. This reflective approach, supercharged by AI tools, directly targets that epistemological stance.

8. Conclusion: The Classroom as a Space for Thinking, Augmented by AI

We began with the assertion that a physics classroom is, above all, a space for thinking. The current model of instruction, with its emphasis on pre-packaged recipes, has inadvertently turned it into a space for recall and application. The rise of AI has not changed this fundamental need; it has amplified it. By making the recipe trivial, AI forces us to return to what truly matters. This paper has argued for a reclamation of that original purpose, with AI as a powerful ally. By foregrounding the subjective, inventive nature of physical theories that is, *by presenting Newton's laws as Newton's laws, not as nature's laws*, we can transform the educational experience. We can invite students to try on the minds of the inventors, to struggle with their struggles, and to feel the power and the peril of creating a personal explanation of the world. AI can sit beside them in this struggle, offering Socratic questions, historical context, and alternative mathematical perspectives.

This does not mean abandoning rigor or mathematical competence. On the contrary, it grounds the mathematics in a rich conceptual soil, giving it meaning and purpose. It means teaching physics not as a monolith, but as a mosaic of brilliant, personal attempts to understand a shared reality. It means allowing students the space to develop their own a priori perspectives, to find the formulation that speaks to them, and to feel the gratitude that comes from recognizing the immense creative effort that built the foundation on which they now stand. In doing so, we do not just teach physics; we cultivate physicists, not just in the professional sense, but in the deepest human sense: as people who think carefully, creatively, and personally about the world around them, using every tool at their disposal, including AI, to see further into the unknown.

Contribution to the Field

This paper contributes a novel theoretical synthesis that integrates generative AI into a historically grounded, reflective physics pedagogy. It bridges PER literature on epistemologies, conceptual change, and metacognition with the affordances of AI, proposing concrete classroom strategies. We offer the following testable propositions to guide future empirical research:

1. Students exposed to historical re-enactment and multiple formulations will demonstrate more sophisticated epistemological beliefs about physics (as measured by the CLASS or MPEX surveys) compared to those in traditional instruction.
2. AI-assisted Socratic dialogue will lead to greater metacognitive awareness and more robust personal mental models, as evidenced by think-aloud protocols and conceptual inventories.
3. The proposed pedagogy will increase students' sense of agency and creativity in problem-solving, measurable through design tasks and reflective essays.

The proposed vision of the physics classroom carries with it a profound re-imagining of the very purpose of education itself. The school, in this framework, ceases to function as an assembly line for a qualified labour force, designed merely to fill predefined roles in existing industries. To conceive of education in such a way is to prepare students for a past that no longer exists, training them to serve machines, both mechanical and now algorithmic, rather than to master them. Instead, the school must be reconceived as a nest for opportunities for future generations. It is a fertile ground where new ideas are germinated, where the intellectual courage to question established recipes is cultivated, and where students are empowered not just to meet the demands of today's job market, but to generate the entirely new industries and unforeseen jobs of tomorrow. The history of physics is a testament to this truth: quantum mechanics was not developed to service the semiconductor industry; rather, the semiconductor industry was born from the revolutionary, personal, and seemingly impractical thinking of those who sought to understand the atom. When we equip students with the capabilities for deep, personal reflection, historical empathy, and creative model-building, these are the very skills this paper advocates for, we are not merely teaching them physics. We are endowing them with the capacity to become the inventors of their own future, to create the industries that do not yet exist, and to solve problems we have not yet imagined. This is the ultimate goal of a truly humanistic physics education: to transform students from passive consumers of knowledge into active architects of a world that is constantly being re-invented.

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