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Critique-Oriented vs. Framework-Oriented Approaches in Education: proposing a middle path for physics teaching based on Thomas Kuhn's philosophy

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ABSTRACT

This study proposes an approach to physics education grounded in Thomas Kuhn's philosophy of science, aiming to achieve a balanced integration between critique-oriented and framework-oriented pedagogical models. The paper begins by critically examining the prevailing emphasis on critical thinking in science education—particularly within physics—and seeks to deconstruct some of its underlying assumptions. Conversely, it explores the framework-oriented approach, often associated with traditional, transmission-focused models of teaching. Drawing on Kuhn's conceptualization of paradigms and research traditions, the study develops an alternative framework that synthesizes the reflective rigor of critique-oriented education with the structural coherence of framework-oriented methods. Ultimately, the paper challenges certain idealized claims advocating for the complete elimination of preconceptions and paradigms, arguing that, from a philosophical standpoint, such claims are both impractical and inconsistent with the nature of scientific inquiry.

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Intruduction

The rapid growth of scientific knowledge, the advent of the artificial intelligence era, and the transformation of information management systems have increasingly challenged traditional educational models, making the adoption of new pedagogical methods essential (Popenici & Kerr, 2017). In this context, rote learning, memorization-focused practices, and teacher-centered instruction have increasingly been critiqued and have lost dominance in modern education. Traditional teacher-centered models are closely associated with transmission-oriented approaches in which the teacher imparts fixed bodies of knowledge and students are expected to absorb and reproduce that content (Brown, 2003; Cornelius-White & Harbaugh, 2010; Schweisfurth, 2013). Critics argue that such models emphasize rote memorization and procedural drills at the expense of deeper understanding, critical thinking, and active engagement (Brown, 2003; Westbrook et al., 2013). Moreover, traditional practices have often been linked to narrow assessments such as standardized testing, where student success is measured primarily by the ability to recall information for examinations rather than to apply, analyze, or synthesize knowledge (Cornelius-White & Harbaugh, 2010; Westbrook et al., 2013).

Contemporary education research increasingly advocates for learner-centered, inquiry-based, and constructivist pedagogies that foster meaningful learning beyond memorization and passive reception. Traditional educational approaches have long been subject to critique by prominent thinkers such as John Dewey (1938) and Paulo Freire (1970), among others. Dewey contends that in traditional pedagogy, students assume a passive role as mere recipients of information, while the teacher functions as the central authority. Learners are thus regarded as "empty vessels" to be filled through repetition and memorization, a process that suppresses creativity and precludes opportunities for meaningful, experiential learning (Dewey, 1938). The traditional classroom is often structured around teacher authority and a rigid transmission of knowledge. Instruction is typically top-down, with the teacher controlling content and pacing, and knowledge presented as fixed and unquestionable. This configuration tends to foster intellectual epistemic dependence, positioning students as passive recipients rather than active participants in inquiry or independent thought.

Similarly, Freire (1970) offers a powerful critique of traditional schooling in *Pedagogy of the Oppressed*, referring to it as a "banking model" of education. In this model, the teacher acts as a "depositor" of knowledge, while students serve as passive "depositories," receiving information without critical engagement. Knowledge, in this context, becomes a static object transferred from teacher to student, thereby foreclosing opportunities for critical reflection or transformation (Freire, 1970). Freire argues that such an approach alienates learners from authentic understanding and compels them to accept existing social and political realities uncritically. As Bhattacharya (2022) observes, students in this model have little opportunity to question or reinterpret knowledge; instead, they merely copy and store information in a rote manner. Overall, traditional classrooms impose a particular form of knowledge superficially and passively, fostering intellectual epistemic dependence centered on the teacher as the embodiment and custodian of authoritative knowledge.

Conversely, in contemporary educational systems, one of the primary objectives is to cultivate learners' critical thinking abilities, enabling them—as informed citizens—to make reasoned decisions in both public and private domains (Ennis, 2018; Hitchcock, 2017). Critical thinking empowers individuals to engage appropriately with evidence (Erduran, 2021), to adopt rational and reflective approaches in the face of unwarranted skepticism (Normand, 2008), and to resist tendencies toward science denial (McIntyre, 2021). Within the scientific community, critical thinking also plays a crucial role in theory construction and the advancement of scientific knowledge (Davidson et al., 2020). From both historical and social perspectives, the cultivation of critical thinking has yielded significant outcomes. Historically, it fostered the emergence of innovative scientific theories, exemplified by Newton and Boyle, who critically interrogated the dominant paradigms and worldviews of their time. Newton, in particular, built upon and extended the critical reasoning developed by earlier figures such as Copernicus, Galileo, and Kepler. Socially, critical thinking has also inspired transformative critiques beyond the scientific realm—for instance, Karl Marx and John Ruskin employed critical reasoning to challenge and reformulate understandings of the capitalist system in the nineteenth century.

Multiple definitions of critical thinking emphasize its role in informed decision-making and the reduction of cognitive bias. Ennis (2002), for instance, defines critical thinking as a form of logical and reasoned thought employed in determining whether to accept or reject a belief, encompassing processes such as generating hypotheses, considering alternative viewpoints, and formulating possible solutions. Similarly, Alper et al. (2015) conceptualize critical thinking as a systematic mode of reasoning and problem-solving essential for effective decision-making, requiring the careful evaluation and interpretation of available information prior to taking action. Moreover, critical thinking is often viewed as the foundation of rational and scientific skepticism, motivating inquiry into claims that lack empirical substantiation (Tena-Sánchez & León-Medina, 2022).

A central challenge of traditional education is its tendency to foster intellectual epistemic dependence among learners. Rooted in teacher-centered structures and hierarchically imposed cognitive order, this model often prioritizes content transmission at the expense of creativity and critical reflection. However, not all aspects of traditional education are problematic. One constructive dimension—what can be termed framework-oriented education—provides a structured scaffold of core concepts and principles, supporting coherent understanding and laying the foundation for further inquiry and critical thinking. Framework-oriented education emphasizes the structured transmission of core concepts and principles, with the teacher guiding learning to ensure coherent understanding. Its focus is on providing a stable conceptual scaffold, allowing students to build knowledge systematically before engaging in independent inquiry or critical analysis. This approach is especially important in disciplines like physics, where conceptual coherence and cumulative understanding are essential. In contrast, contemporary educational paradigms—emerging partly as a response to such traditionalism—emphasize critique-oriented education, which aims to nurture inquiry, creativity, and critical thinking in learners. However, a persistent tension exists between these two orientations. An excessive focus on critique, with its emphasis on continuous questioning and epistemic challenge, risks generating conceptual fragmentation and the neglect of structured content delivery (as will be discussed in Section 3). Conversely, an extreme framework-oriented stance suppresses learners' intellectual autonomy and capacity for inquiry.

In science education, the longstanding challenge of balancing instructional structure with opportunities for student autonomy has been widely examined. Foundational scholarship on approaches such as Guided Discovery Learning (Bruner, 1961; Mayer, 2004) and later developments in Scaffolded Inquiry (Wood, Bruner, & Ross, 1976; Quintana et al., 2004; Bell, Blair, Crawford, & Lederman, 2005) reflect sustained efforts to design learning environments that foster active engagement while mitigating the cognitive demands associated with minimally guided instruction. A substantial body of research demonstrates that students acquire scientific concepts and practices more effectively when exploratory activities are embedded within intentional and well-structured supports (Hmelo-Silver, Duncan, & Chinn, 2007). Building on these insights, the present paper advances a philosophically grounded framework that extends this line of inquiry by arguing that the productive coordination of structure and agency is not merely a pedagogical technique but a reflection of the epistemic dynamics that characterize scientific practice itself. The importance of linking philosophical perspectives with science education not only shapes how students and teachers perceive the nature of science (see, e.g., Lederman, 2006; McComas, 2020; Sajadi, 2025b) but also bears on broader issues of character formation in science instruction (see, e.g., Sajadi, 2025a).

Within the context of science education, and particularly physics education, this duality gives rise to several important questions: Is a wholly critique-oriented approach to physics teaching feasible? Can traditional, framework-oriented elements be eliminated from effective instruction? Which orientation more effectively supports learning in physics, and which aligns more closely with the epistemic nature of the discipline itself? Addressing these questions necessitates a coherent methodological and philosophical framework. Assuming that meaningful learning in physics remains a central curricular goal, this study draws upon Thomas Kuhn's philosophy of science to explore whether a balanced, integrative approach can be developed—one that mediates between framework-oriented and critique-oriented models of education.

In other words, this study seeks to propose—drawing upon Thomas Kuhn's philosophy of science—an appropriate middle path between the dichotomy of the traditional framework-oriented approach and the modern critique-oriented approach in education. The aim is to enable physics instruction to overcome the limitations inherent in both orientations, or at least to establish a productive balance between them. Our central claims regarding these two pedagogical orientations are as follows: first, the critique-oriented approach, while valuable for fostering inquiry and intellectual autonomy, should be tempered, as its unqualified or extreme adoption may lead to instability and the neglect of structured knowledge. Second, the framework-oriented approach, despite the intensity of contemporary criticisms directed against it, is not devoid of pedagogical merits; rather, it retains important functions in organizing learning and ensuring epistemic coherence. These two claims together suggest the need for a mediated, integrative framework that reconciles critical engagement with cognitive structure. Drawing on Kuhn's The Structure of Scientific Revolutions (1962/1996), this study conceptualizes such a middle path as a means of establishing equilibrium between critique and epistemic dependence within educational practice—particularly in the context of physics education.

At this stage, an important clarification is necessary. Thomas Kuhn's The Structure of Scientific Revolutions has been widely discussed within educational research (cf. Matthews, 2022). However, the present study adopts an interpretive stance that diverges markedly from dominant trends in this literature. Educational theorists have frequently invoked Kuhn's Structure to support constructivist orientations in education (Hawkins, 1994; Novak, 1977). Such interpretations often entail philosophical implications associated with constructivism—namely, skepticism toward the possibility of absolute truth (von Glasersfeld, 1989), doubts regarding scientific objectivity (von Glasersfeld, 1993), and tendencies toward epistemic relativism (Quale, 2008). These consequences, however, concern broader philosophical debates about the nature of scientific knowledge and remain contested among philosophers of science. It is essential to underscore that our engagement with Kuhn's Structure as a foundation for balancing educational approaches does not entail a commitment to constructivism. For this study, Kuhn need not be interpreted through a constructivist lens. The central claim we derive from his philosophy is that education inherently involves an element of epistemic dependence, and consequently, an effective pedagogy must integrate framework-oriented and critique-oriented dimensions in a balanced manner. Whether this inevitable epistemic dependence is ultimately compatible with rationality, objectivity, or scientific realism constitutes a separate philosophical issue—one that lies beyond the scope of the present inquiry.

The structure of the paper is as follows. Section 2 provides a detailed examination of the critique-oriented dimensions of contemporary educational approaches. Section 3 argues that an exclusively critique-oriented model is neither feasible nor pedagogically effective in the context of physics education, and that a certain degree of framework-oriented instruction remains indispensable. Section 4 elaborates Kuhn's perspective, demonstrating that his account of scientific knowledge—particularly within the field of physics—implicitly incorporates elements of framework-oriented learning. Finally, Section 5 presents concluding remarks and pedagogical recommendations aimed at developing a more balanced and contextually relevant framework for physics education.

1. Critique-Oriented Teaching

In this section, we examine several influential modern educational theories—including Freirean critical pedagogy, Derridean deconstruction, and constructivism—that have each challenged traditional models of education. At the outset, it is essential to emphasize that these approaches are philosophically heterogeneous and pursue different ultimate aims: Freire's project is grounded in political liberation, Derrida's in the critique and deferral of fixed meaning, and constructivism in the learner's active construction of cognition. These differences are neither trivial nor incidental to their respective traditions. However, for the limited analytical purpose of this paper, we group them under the umbrella of "critique-oriented education" to highlight a single pedagogical feature they share: a principled skepticism toward the passive transmission of a fixed body of knowledge and a corresponding emphasis on learner agency, dialogue, questioning, and meaning-making. This categorization is not meant to collapse their ontological or teleological distinctions, but to isolate a common pedagogical thread that contrasts sharply with the framework-oriented dimension of education, which stresses the structured transmission and internalization of knowledge. Our goal is therefore not simplification, but conceptual abstraction: to identify a shared pedagogical impulse relevant to the argument that follows, without implying philosophical equivalence.

Given the pressing need to rethink and reform traditional educational models, scholars have proposed alternatives to the teacher-centered paradigm. Notably, Freire (1970) advocates a "dialogical education" model, in which teachers and students engage as equal participants in the learning process. He argues that education should cultivate critical consciousness, enabling individuals to become aware of their social and global conditions and to take informed action to transform them (Freire, 1970, 79). Within this framework, students are not passive recipients of knowledge but active agents who analyze, interpret, and ultimately seek to transform their environment. Freire emphasizes that education should be a liberatory practice, encouraging learners to perceive the world not as a fixed reality but as a dynamic, changeable construct (Freire, 1970, 83). While Freire's primary focus is on social and political empowerment—particularly the liberation of oppressed populations—what is especially relevant to contemporary physics education is his emphasis on dialogue and the equitable participation of teacher and student, an aspect that informs the critique of traditional pedagogical hierarchies and guides our consideration of more interactive approaches in science teaching.

The "Clubhouse Class" aligns closely with Freire's critique of "banking" education. Like Freire's problem-posing pedagogy, it replaces hierarchical knowledge transmission with dialogue, collaboration, and shared epistemic agency. Students and teachers learn together through inquiry, not through one-way instruction. The model's emphasis on autonomy, choice, and collective meaning-making reflects Freire's vision of education as a liberatory process that develops learner agency rather than obedience. The educational foundations of what is now described as a Clubhouse Class can be traced to the Computer Clubhouse, an influential informal learning environment established in 1993. The model was developed through a collaboration between Natalie Rusk, Mitchel Resnick, and Stina Cooke at The Computer Museum (Boston) in partnership with the MIT Media Lab's Lifelong Kindergarten Group (Rusk, Resnick, & Cooke, 1999; Resnick, Rusk, & Cooke, 1998). Rooted deeply in Papert's constructionist epistemology, the Computer Clubhouse was designed as a community space where young people could develop technological fluency by engaging in personally meaningful, self-directed projects rather than following a prescribed curriculum (Papert, 1980; Kafai, Peppler, & Chapman, 2009). While the original Clubhouse was conceived as an after-school program, its underlying principles—interest-driven participation, low hierarchy, collaborative knowledge building, and authentic engagement with tools and practices—have since been adapted into formal educational settings. The term "Clubhouse Class" does not originate from a single author; rather, it designates classroom environments modeled on the ethos of the Computer Clubhouse. In this translation from informal to formal learning, the essential pedagogical logic remains consistent: learners pursue inquiry trajectories that matter to them, expertise is distributed rather than centralized, and the teacher's role is primarily that of mentor or facilitator. Thus, the Clubhouse model represents a significant pedagogical paradigm that challenges traditional transmissive instruction by foregrounding participation, creativity, and agency (Resnick, 2017).

This "clubhouse class" idea does not advocate replacing conventional classroom platforms such as Skyroom; instead, it emphasizes features such as decentralization, horizontal relationships, spontaneity, and confrontational dialogue, which distinguish Clubhouse interactions from more conventional educational models. In this framework, the classroom requires an environment and a teacher that are markedly different: a teacher who, rather than repeatedly presenting predictable, outdated notes, is prepared—intellectually, ethically, and behaviorally—to transform the classroom into a lively scientific dialogue full of engagement (Badamchi, 2021). The central principle of this idea is to prioritize dialogue and questioning while reducing the teacher's central authority, thereby limiting passive student epistemic dependence. To illustrate this idea more clearly, we can refer to the instructive recollections of Richard Feynman (a renowned physicist and Nobel laureate), which effectively demonstrate the impact of dialogue-based, interactive, and Clubhouse-like teaching:

For my lesson, my father would begin by having me look at something, say, a toy dog that runs along the floor. "What makes it move?" he would ask. "The sun," I would say, for he had taught me that energy comes from the sun. "No, no," I would correct myself, "it moves because I wound it up." "And why are you able to wind it up?" "Because I eat," I would answer. "And what do you eat?" "Plants." "And how do the plants grow?" "They grow because of the sun." (Feynman, 1969, 317)

If we examine the dialogue between the teacher (father) and the student (son), the central idea—the emphasis on dialogue and its role in critical learning—becomes evident. The teacher engages the student by asking questions about tangible and comprehensible phenomena (such as winding and movement of the toy, sunlight, the role of plants in the food chain, and the role of sunlight in plant growth), thereby facilitating learning through dialogue. This anecdote is a strong example of engaging, critique-oriented learning. Learners exposed to such methods deeply experience the joy of learning.

In line with this perspective, deconstructionist approaches—particularly Derrida's—offer a useful lens. Philosophically, deconstruction involves critically rereading texts, exposing hidden assumptions, and challenging fixed meanings. Translated into educational practice, it invites a re-examination of established structures such as classroom organization, teacher–student power relations, curriculum, assessment, and the status of knowledge itself. What appears "normal" is revealed as a product of discourse and authority, and therefore open to revision. In contrast to traditional, teacher-centered instruction centered on hierarchical knowledge transmission, deconstruction highlights cognitive diversity, experiential difference, questioning, dialogue, and critical reflection. This orientation aligns closely with Critical Pedagogy and Inclusive Education, which foreground equality, empowerment, and the valuing of difference (Burbules, 1996).

Deconstructionists argue that in traditional and conventional teaching, little attention is given to cognitive, individual, and social differences; instead, knowledge transmission is a primary educational goal. Deconstruction emphasizes attention to individual and social differences among learners. Understanding diverse perspectives and a wide spectrum of mentalities enables teachers to incorporate these differences into teaching styles, allowing learners to engage with new perspectives and benefit fully from both the quality and quantity of educational experiences. Derridean deconstruction, operating within an entirely different philosophical tradition, similarly challenges transmission-oriented education—not by pursuing political liberation, but by interrogating the stability of meaning, authority, and "normal" structures in educational practice (Burbules, 1996). Applied pedagogically, deconstruction invites teachers to question inherited assumptions about curriculum, classroom hierarchy, and learner identity, thereby creating space for diverse perspectives and collaborative meaning-making (Arató, 2014; Fiume, 2005). Here, too, the resistance to passive knowledge transfer emerges from a commitment to epistemic openness and interpretive plurality.

According to deconstructionists, in the dominant traditional teaching style, emphasis on normalization and homogeneous knowledge transmission neglects individual, cognitive, and social differences among students. This critique stems from post-structuralist roots, which view structures not as natural but as products of discourse and hidden power relations (Burbules, 1996). From an educational perspective, deconstruction suggests that teachers should critically review existing educational structures and design teaching styles that are flexible and compatible with the cognitive, cultural, and social diversity of learners (Arató, 2014). In this approach, differences are seen not as problems but as learning resources, and the classroom becomes a space to encounter diverse perspectives and create new meanings (Fiume, 2005). From the deconstructionist perspective, the dominant hierarchical teacher-student relationship is replaced by a collaborative and relational dynamic. The deconstructive teacher is not merely a transmitter and reproducer of knowledge but participates alongside learners, establishing an affective relationship and facilitating the learning process. Students become the primary producers of knowledge and ideas (Khabbazikenari & Rahbar, 2022).

Constructivist approaches are also relevant. Grounded in cognitive science rather than political theory or post-structuralism, constructivism rejects passive transmission by viewing learning as an active process in which students construct understanding through engagement and problem solving. Teachers function as facilitators who support inquiry, peer interaction, and meaning-making rather than as authoritative knowledge providers (Hmelo-Silver et al., 2007; Sengupta-Irving & Enyedy, 2015). Constructivist learning is student-centered: learners actively derive meaning from experience, while teachers and resources serve to guide and scaffold the process. Unlike teacher-centered approaches, where instructors define problems, model solutions, and direct application, constructivist classrooms encourage students to generate solution pathways, discuss and refine ideas with peers, and justify their reasoning. Here, teachers act as guides, offering strategic hints and support rather than delivering fixed answers, thereby fostering critical thinking, inquiry, and learner autonomy (Sengupta-Irving & Enyedy, 2015; Hmelo-Silver et al., 2007).

Despite their profound philosophical differences, these approaches share a limited but significant pedagogical similarity: they all challenge hierarchical, transmission-based teaching by emphasizing the learner's active role in constructing, interpreting, or questioning knowledge. In this explicitly pedagogical sense, they can be grouped as critique-oriented. Taken collectively, these perspectives highlight one side of a broader tension in contemporary education. Although each offers a different rationale for reducing teacher authority and enhancing learner agency, they converge in aiming not merely to transmit knowledge but to transform teacher–student relationships by empowering students to inquire, critique, and generate knowledge independently. This shared orientation, however, raises a central question—especially for disciplines such as physics: to what extent can critique-oriented approaches replace, or must they instead coexist with, the framework-oriented elements that provide conceptual coherence and disciplinary structure? In short, can the framework-oriented dimension of education be fully eliminated, or is it an indispensable counterpart to critique-oriented practice?

2. The Critique-Oriented/Framework-oriented Dichotomy: Determining Boundaries and Significance in Physics Education

In this section, we will show that, contrary to the modern approaches mentioned above, physics education cannot be entirely devoid of framework-oriented aspects. Our goal is not to challenge dialogue, critical learning, or the social concerns of critique-oriented approaches, but rather to determine their boundaries and degree of importance in physics education. The question is whether the ideal of a "good classroom" consists solely of dialogue and engagement or the complete avoidance of student epistemic dependence. Clearly, during these dialogues, educational content must also be conveyed or reinforced. Considering the characteristics of physics classrooms, we propose three points to complement and refine critique-oriented education:

First, some essential skills for laboratory work and observations cannot be transferred through engaged dialogue alone. Without these skills, students cannot achieve the experimental and observational results that scientists obtain. Consider, for instance, the skills required to use a microscope. Can the fundamental skills for operating a microscope be conveyed through engaged dialogue? Therefore, in this aspect of education, minimal epistemic dependence and imitation seem more or less inevitable. Moreover, these skills cannot be learned merely through observation or listening; they must be acquired through practical, framework-oriented training, highlighting the necessity of hands-on education.

Second, mathematical skills and foundational principles necessary for explaining and addressing physical problems cannot be taught in physics classes solely through engaged dialogue. Can Newtonian mechanics or quantum mechanics—regardless of the instructional method—be taught without the proper mathematical background? Here, we are compelled to accept at least the foundational principles of certain sciences, including mathematics. Furthermore, consider a student who, relying on their realist intuition, questions the principles and theoretical basis of quantum theory (for example, regarding causality or the physical interpretation of propositions). In this case, engaged dialogue and questioning will not only fail to produce meaningful outcomes but may also prevent the student from recognizing or attempting to understand the theory's achievements due to perceived incompatibility with their intuitive understanding.

Third, a critical stage of education is the formation of concepts in the student's mind. It seems impossible to convey theoretical concepts such as electrons and protons merely through dialogue, or to conduct appropriate observations with a mind devoid of these concepts. It is therefore preferable for the teacher to convey these concepts through an articulate explanation. To illustrate this, we return to Feynman's anecdote. At the beginning of the quote, he explicitly states:

For my education, my father dealt with the concept of energy. He would deal with the idea before he used the word (Feynman, 1969, 317).

Without a framework-based understanding of the concept of energy—which provides a foundation for forming even an initially incoherent view of the concept, as well as a basis for discussing it—the ensuing conversation could not have had any meaningful content. In Feynman's example, the teacher first introduces the concept of energy so that the student can form an initial idea about it; only then can the teacher meaningfully discuss the relationship between solar energy and other phenomena. Moreover, the elements addressed in the dialogue—such as winding and moving the toy, sunlight, the role of plants in the food chain, and the effect of sunlight on plant growth—are simple and familiar aspects of everyday experience. By contrast, the phenomena encountered in more advanced scientific contexts are rarely so straightforward. Most require substantial explanation and sustained instruction for students to develop even a basic understanding. In Feynman's example, the father does not convey abstract formulas or dry definitions; rather, he cultivates a kind of "physical intuition" through engagement with observable phenomena. This approach aligns more closely with inquiry-based learning than with the direct transmission of knowledge. Nevertheless, in the early stages of learning, some foundational principles remain necessary to establish a conceptual framework that makes later discussion and inquiry possible.

Another example can help clarify this point. This example is drawn from an article introducing the Predict-Observe-Explain (P.O.E.) method (Sedaqat et al., 2019). According to this method:

1. The lesson begins by posing a question that stimulates student curiosity. The student is asked to predict the outcome using scientific reasoning and to think about the cause of their prediction.
2. Next, a designed experiment is conducted, and students must observe carefully and record their observations.
3. Finally, once students have obtained results, they must explain their responses and provide sufficient justification.

Consider a circuit given to students with the following question: In the circuit below, when the switch is closed, how does the reading on the ammeter change?

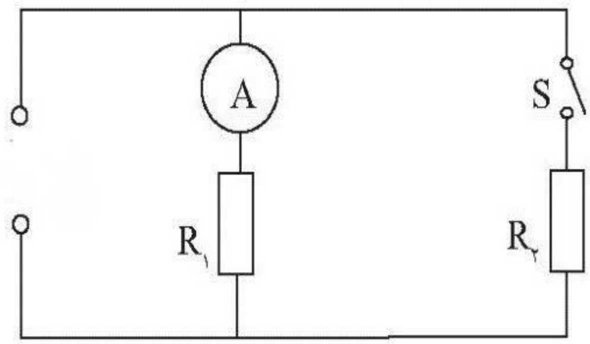

Figure 1. *The given Circuit to students*

Clearly, if a student lacks prior familiarity with electrical circuit concepts, they cannot provide a prediction, and even after experimenting, they cannot explain the observations and results as a physicist would. Therefore, the authors emphasize that students in the class have been taught series and parallel connections of resistances, and they have learned the relationships among potential difference, current, and equivalent resistance in both cases (Sedaqat et al., 2019). It seems evident that in such educational scenarios, reliance on purely engaged dialogue is insufficient. It is preferable for the teacher to first articulate the necessary concepts, guiding students through the ideas and procedures so that meaningful comprehension can occur.

The dialogue or the teacher's role as a "facilitator" can only effectively take place after the relevant concepts and experiments have been taught—i.e., after the framework-oriented acquisition of concepts and skills. Without these foundational ideas, dialogue is meaningless and lacks substance. In a Clubhouse-style classroom, if students resist or struggle against these foundational and often framework-oriented teachings, they cannot observe or understand the experimental achievements of scientists, let alone engage in meaningful dialogue about them.

We do not, however, deny the importance of dialogue in education. For instance, a teacher may, after transmitting the concepts and arranging the experiment, engage students in an interactive discussion to interpret the results, guiding them toward the standard interpretations used by scientists. Here, the teacher fulfills the role of a facilitator. Nevertheless, we argue that ideal education encompasses multiple features: engaged dialogue or critique-oriented teaching is only one of them, and the presence of certain framework-oriented elements is unavoidable.

3. A Kuhnian Philosophy of Science Approach to Judging the Critique-Oriented/Framework-oriented Dichotomy in Education

In addition to the points mentioned above, we now turn to the philosophy of science to further evaluate our claims about the critique-oriented approach. Is it possible, using a Kuhnian Perspective on the philosophy of science, to judge the importance of incorporating certain framework-oriented aspects into education? A closer look at Thomas Kuhn's *The Structure of*

Scientific Revolutions reveals an approach that conflicts with the wholesale, one-dimensional dominance of critical thinking and questioning, and aligns, in a sense, with the three points raised in the previous section. More precisely, the three points mentioned earlier are part of an integrated whole in physics, which is referred to as a paradigm or research tradition. We explain this concept and its relation to education by drawing on Kuhn's perspective.

Kuhn (1996), in The *Structure of Scientific Revolutions*, emphasizes that much of the educational process involves learning through exemplars—typical problem-solution pairs and puzzle-solving patterns. Within each paradigm, there exist models for solving puzzles—that is, for matching new phenomena to the theory. The educational system and instructors aim to prepare students so that, after completing their courses, they can independently solve new puzzles by applying these models.

Puzzle-solving, in Kuhn's terms, has a specific meaning: it is an activity in which the scientist uses the rules and methods defined by the paradigm to increase the degree of correspondence between nature and the paradigm (Kuhn, 1996, 30). If we think of the paradigm as a box, science "seems an attempt to force nature into the preformed and relatively inflexible box that the paradigm supplies" (Kuhn, 1996, 57). Paradigmatic education teaches students how to fit nature into a pre-constructed conceptual "box." The primary activity is not to critique the box but to find ways to organize the elements of nature within it.

Normal science… is a strenuous and devoted attempt to force nature into the conceptual boxes supplied by professional education (Kuhn, 1996, 24).

Students acquire the skill of using these models while solving exemplar problems and standard examples. Education proceeds by explaining the mathematical rules and relationships between symbols, alongside specific examples illustrating how they function in practice (particularly in matching theory to nature). Working through exemplars helps students see and categorize natural phenomena as the instructor and the scientific community do. Through this process, the particular way of seeing and interpreting physical phenomena becomes internalized in the student.

What the student must learn, whether from a textbook or a laboratory, is to see the situations that confront him as like the ones he has already encountered. He must, that is, learn to see [nature] as other members of his specialist group (Kuhn, 1996, 187).

Kuhn explicitly states that the goal of education is to create a shared vision between the student and the expert community. This process constitutes a form of epistemic dependence; the student must view the world through a pre-determined perceptual model called a paradigm. This is precisely in contrast to inquiry-based education: the student is not taught to critique, but to achieve cognitive conformity.

Consider Newton's Second Law ($\vec{F} = m\vec{a}$) as an example. According to Kuhn, what is most important is not merely the application of the mathematical and logical relations associated with the law (e.g., acceleration, mass, and force). By observing how exemplar problems related to the law are solved in different contexts, the student does not simply learn to apply these relations. More fundamentally, the student develops the ability to recognize (or organize) other physical phenomena in terms of the symbols, enabling them to engage in puzzle-solving for unknown physical phenomena and match theory to nature. This ability arises from identifying similarities between exemplar situations and new situations. The crucial aim of education is to cultivate this ability to perceive and interpret novel situations as one would perceive exemplar cases, after which the application of logical and mathematical relations follows. Newton's Second Law manifests differently in different cases:

a) In the simple pendulum: $mgsin\theta = -\mathrm{ml}\frac{\mathrm{d}^2\theta}{\mathrm{dt}^2}$

b) In free fall: $mg = \mathrm{m}\frac{\mathrm{d}^2\mathrm{s}}{\mathrm{dt}^2}$

In both cases, finding similarities in physical phenomena and connecting them to the Second Law occurs through exemplar-based learning. It is through solving exemplars that methods of applying Newtonian laws to astronomical motion, pendulums, or billiard ball collisions are internalized. Through these examples, students learn to see similar situations as analogous, and additionally, these organized situations serve as canonical instances for applying a scientific law.

In the process depicted by Kuhn, one cannot assign a prominent role to critical questioning; the role of epistemic dependence is central.

The most striking feature of the normal research problems we have just encountered is how little they aim to produce major novelties, conceptual or phenomenal (Kuhn, 1996, 35).

The goal is to fit the paradigm to nature (i.e., puzzle-solving in its specific sense), not to change the paradigm itself. Creativity is needed, but all creativity is constrained by this goal: "attempt to make nature fit the box" (Kuhn, 1996, 52).

The student must learn the ways of seeing and interpreting physical phenomena through exemplar cases in order to organize them. How we categorize and classify phenomena to place them under a law is largely imposed on the student through the paradigm. In this learning process, resistance, critique, and confrontational questioning have little place; instead, emphasis is placed on framework-oriented learning or on the internalization of a specific way of perceiving, interpreting, and organizing physical phenomena. Student questioning is primarily for understanding, not for challenging the paradigm or the research tradition.

It should be noted that meaningful experiences in physics education, or the logical inferences emphasized in active learning methods such as inquiry-based learning, are impossible without the prior internalization—often framework-oriented—of a specific way of perceiving phenomena (within the Kuhnian paradigm). Before the continuity of a paradigm, scientific activity is scattered and purposeless, since phenomena cannot be considered meaningful or connected without a paradigm.

In the absence of a paradigm or some candidate for paradigm, all of the facts that could possibly pertain to the development of a given science are likely to seem equally relevant (Kuhn, 1996, 113).

A paradigm is a necessary framework for giving meaning to facts. Without this framework, the student is overwhelmed by a multitude of seemingly unrelated data. Therefore, effective education must "impose" this framework on the student so that they can perceive the world meaningfully. This provides a strong justification for initial epistemic Dependence: such Dependence is a prerequisite for any meaningful scientific activity.

Consider a physical theory, such as atomic theory. Kuhn, using John Dalton's atomic theory as an example, demonstrates the central role of paradigms in the development of science. He argues that the development of this theory was not simply the result of collecting experimental data; it was made possible by the prevailing theoretical framework in chemistry at the time. Before Dalton's theory was accepted, chemists could not recognize multiple ratios in chemical compounds because the prior paradigm lacked concepts such as "atom" and "fixed ratios." The new paradigm not only guided research questions (e.g., "How do atoms combine?") but also determined experimental methods. Kuhn emphasizes that only after the acceptance of atomic theory did chemists develop techniques to measure multiple ratios—techniques that were themselves based on the theory (Kuhn, 1977). This Kuhnian example shows that experimental data and experience are meaningless in a theoretical vacuum; they can only be interpreted within a paradigm. For instance, the mass ratio of oxygen to hydrogen in water (1:8) would have seemed a random number before Dalton's theory, but under the new paradigm, it became evidence for atoms with fixed ratios. This interdependence between theory and observation highlights three key points: first, paradigms determine what counts as "valid" data; second, paradigms help categorize empirical data conceptually; and third, obtaining meaningful experience without theoretical assumptions is impossible. According to Kuhn, even the selection of laboratory instruments is influenced by the paradigm, indicating that at least part of meaningful experience, as discussed by Dewey, depends on the prior internalization of concepts.

In inquiry-based learning (Bruner, 1961), clues are provided to help students derive logical conclusions themselves (Mayer, 2004). However, excessive simplifications of these clues are often observed. Some researchers have emphasized the necessity of proper guidance to prevent student confusion (Hmelo-Silver et al., 2007). From our perspective, these clues, which enable the student to reach logical conclusions in the final stage, are only possible through the prior acquisition—often framework-oriented—of a particular way of perceiving phenomena (a paradigm). Kuhn explains this well, and it is often overlooked in modern approaches.

Now, with regard to Kuhn's description of how learners are educated and the role of learners in future scientific activity, we can clearly observe that the educational process leading to science within a paradigm or research tradition involves elements of both critique-oriented and framework-oriented approaches. In this process, the learner is not expected, through dialogue, to challenge the core elements of the paradigm or to continuously revise their interpretation of empirical and perceptual phenomena through repeated questioning. Kuhn emphasizes that scientists, in much of their work, adopt a non-critical stance toward their paradigm and are indifferent to innovations proposed by others as alternatives.

> … those [phenomena] that will not fit the box [paradigm] are often not seen at all. Nor do scientists normally aim to invent new theories, and they are often intolerant of those invented by others (Kuhn, 1996, 80).

A non-critical approach to the paradigm, combined with a focus on a narrow subject, is essential for further elaboration (increased precision and depth) of research within the paradigm:

By focusing attention upon a small range of relatively esoteric problems, the paradigm forces scientists to investigate some part of nature in a detail and depth that would otherwise be unimaginable (Kuhn, 1996, 37).

Of course, creativity also plays a role here in solving new puzzles (toward the expansion of the paradigm), but this creativity is not intended to challenge the principles and foundations of the research tradition or the paradigm. Challenging the paradigm and research tradition is only a part of the scientific process that occurs during crises or when a paradigm fails, i.e., during a scientific revolution. That is, when a scientist cannot solve a problem, they do not immediately question the paradigm or critique its elements. Indeed, challenging a paradigm is both a time-consuming process and requires the presence of multiple factors (including the construction of a competing paradigm), which cannot be accomplished merely through questioning or undermining the structure and paradigm.

While it is true that the construction of a new paradigm and theories require critique and questioning, it is also incorrect to assume that mere questioning and critique will automatically dismantle an old paradigm and establish a new one. The emergence of a new paradigm or research tradition also requires time, the development of new skills, the maturation of its elements, and the presentation of significant scientific achievements.

Our central argument is not a denial of the importance of critique-oriented approaches or creativity, but rather an effort to situate them within a proper context. According to Kuhn's philosophy of science, scientific activity alternates between periods of normal science—problem-solving within a prevailing framework—and occasional paradigm shifts, in which the fundamental conceptual structure of a discipline is reorganized (Kuhn, 1996). During normal science, practitioners work within shared assumptions and exemplars that define the discipline's problem space, whereas revolutionary episodes occur when accumulating anomalies challenge and reconfigure those assumptions. Education in schools and universities can be understood as operating within a similar paradigm. Textbooks are written according to the accepted framework, teachers generally remain within its boundaries, and students—like normal scientists—primarily engage in puzzle-solving within established knowledge. Only when students confront discrepancies or anomalies in their understanding do they engage in a form of conceptual "revolution," analogous to scientific paradigm shifts. Research in science education has drawn on this analogy to conceptualize student conceptual change, emphasizing that learning often involves restructuring existing understandings rather than merely accumulating information (Posner, Strike, Hewson, & Gertzog, 1982; Matthews, 2024). Within this framework, students initially engage with knowledge structures as normal scientists do, acquiring accepted principles and performing routine problem-solving. As learning deepens, they encounter educational "anomalies"—conflicts or challenges in their own understanding—which can prompt critical engagement and conceptual restructuring. In this way, student learning requires foundational knowledge while simultaneously fostering iterative inquiry, problem-solving, and reflection, mirroring the detection of anomalies and conceptual transformation characteristic of scientific practice.

Beyond the creativity exercised within a paradigm for puzzle-solving, the significance of creativity during revolutionary phases must also be acknowledged. During periods of crisis and scientific revolution, critique, questioning, and creativity gain paramount importance. However, it is crucial to recognize that such critique is preconditioned; its most vital prerequisite is the failure of the paradigm's tools to align the paradigm with nature. Kuhn observes that a scientist initially attributes their inability to achieve this alignment to their own deficient puzzle-solving skills. Only subsequently is this persistent failure linked to inherent weaknesses and inadequacies within the paradigm's own toolkit. It is from this point onward that the importance of creativity and innovation peaks—precisely when a scientist, despite possessing the paradigm and resorting to its tools, fails to reconcile it with nature (though creativity in the very act of attempting this alignment for puzzle-solving remains significant). Criticisms and questions must therefore be rooted in examining the paradigm's failure to align with nature.

Here, the educator can elucidate the anomalies and crises confronting a paradigm. Through dialogue, they can explain how the paradigm lacked the necessary tools for alignment, thereby creating the need for its displacement. Consider, for instance, the paradigms of classical physics and quantum physics. The paradigm of classical physics, predicated on continuity, could not explain phenomena such as the photoelectric effect and faced a crisis. It was at this juncture that individuals, through their creativity, began advocating for a paradigm shift, moving beyond the continuous worldview. Einstein, by quantizing light, successfully explained the photoelectric effect, thereby paving the way for the establishment of the quantum paradigm.

The crucial point is that the student must first comprehend how viewing the world as continuous, despite its intuitive and seemingly self-evident nature, failed to explain certain microscopic phenomena. It is here that questioning becomes critically important. The paradigm's failure to align with nature in explaining the photoelectric effect challenges its very foundation. Critiques and questions directed at this failure to align are the ones deemed substantive. Following the classical paradigm's failure—due to its commitment to continuity—to explain the photoelectric effect, individuals, leveraging their creativity, proposed a "quantum" perspective, effecting a paradigm shift. Appreciating the creativity inherent in this shift is contingent upon the student's prior familiarity with the crisis facing the old paradigm and their understanding of the inadequacy of its tools, such as the continuous worldview, in explaining microscopic phenomena.

Therefore, the role of creativity and questioning—undeniable as it is during periods of normal science for puzzle-solving—reaches its zenith during episodes of crisis and scientific revolution. By introducing the crises confronting a paradigm and facilitating dialogue about its failure to align with nature, the teacher can more effectively and authentically, in harmony with the history of science, illustrate the importance of revolutionary, creative, and transformative innovations. In this sense, we do not intend to deny the significance of the questioning and creativity championed by critique-oriented pedagogies, but rather to place them in their appropriate context.

Even within the narrative of a paradigm shift, framework-oriented dimensions continue to exert their influence in the background. The very ability to meaningfully recognize and articulate a crisis is itself dependent on the paradigm; it is the paradigm that defines what constitutes an anomaly and a failure, whether the world is viewed as continuous or discrete. While our narrative of the shift in physics paradigms has focused on the discrete versus continuous views of the world, it is important to acknowledge that within this same paradigm shift, many other potentially relevant aspects have been overlooked. This leads to the internalization of an educational trajectory along a specific path, where discreteness and continuity are emphasized as pivotal in the two paradigms. This observation, however, is not meant to deny the importance of this narrative, for ultimately, within it, we witness the endeavor to align the paradigm with nature.

While our pedagogical approach distinguishes between a framework-oriented phase and a subsequent phase of critical dialogue, this structure should not be understood as a simple temporal sequence in which students are first educated dogmatically and only later invited to critique. Rather, we argue that the development of a critical mindset must begin within the framework-oriented stage itself. Framework-based instruction provides learners with the conceptual resources and epistemic stability necessary to participate meaningfully in later critical discussions; however, it does not require suspending critical sensibilities altogether. Even in this initial stage, teachers can foreground the provisionally of scientific models, the existence of alternative formulations, and the historical contingency of established frameworks. Such moves cultivate a latent critical awareness without overwhelming students with premature meta-level critique.

Overall, the transition to explicit critical dialogue is not a sudden shift from obedience to critique, but rather an expansion of reflective practices already established during the framework-oriented phase. This approach avoids the difficulty highlighted by Meno's Paradox: students are not expected to generate critical perspectives ex nihilo after a period of purely dogmatic instruction. Instead, they gradually acquire both the conceptual tools and the epistemic disposition needed for critique. Thus, the model departs substantively from traditional sequencing by embedding critical orientation from the outset, even as it acknowledges the pragmatic need for structured conceptual scaffolding before sustained philosophical examination can occur.

From Kuhn's perspective, posing challenging questions and giving learners the space to "approach the world with different and novel perspectives"—as deconstructionists emphasize—is not only not particularly conducive to the elaboration and development of an established paradigm, but can also hinder the expansion of paradigms in physics. This excessive emphasis on different and novel perspectives becomes decisive only during major scientific revolutions. We do not deny this role; however, the issue is that the holistic nature of the structure of physics, which develops over a long and iterative process, must also be considered. Deconstruction, without attention to this aspect of science—where a non-critical approach is sometimes necessary—cannot constitute an appropriate approach to education, at least in physics.

Conclusion

This study began by addressing the issue that conventional physics education, traditionally, possesses a framework-oriented nature and, as a result, cultivates passive and compliant learners. In contrast, the critique-oriented approach, emphasizing questioning, reflection, and active dialogue, has emerged as a reaction to this situation. Our main question was whether, based on Thomas Kuhn's philosophy of science, a middle path could be found between these two approaches—a path that maintains conceptual discipline in science while also enabling critical dialogue and reflective thinking.

First, it must be acknowledged that in physics education, certain fundamental concepts, axioms, and basic skills require structured and guided instruction. Therefore, free and fully critical dialogue is not feasible at all stages of learning. Nevertheless, dialogues aimed at connecting theoretical concepts with empirical evidence should remain an inseparable part of the teaching-learning process. From Kuhn's philosophical perspective, the framework-oriented aspects of education here are undeniable, because any scientific education inevitably involves the transmission of a "specific way of seeing and interpreting phenomena" within the framework of a paradigm.

Second, the acceptance of these framework-oriented elements calls for a reconsideration of teaching methods. Accordingly, avoidance of extremes in both epistemic dependence and critique is recommended. In a framework-oriented approach, reliance on rote memorization and textual reproduction should be avoided, while creating opportunities for comprehension-focused questioning; even though the role of epistemic dependence as a means of instilling a scientific perspective remains essential. Conversely, a critique-oriented approach should not be pursued to such an extent that it undermines established scientific paradigms; as Gillies (1993) notes, testing any scientific proposition requires the temporary acceptance of other propositions. Consequently, critical dialogues are impossible without a set of shared assumptions.

Finally, this study proposes the creation of a dynamic balance between framework-oriented and critique-oriented approaches in physics education. This balance is realized by shifting the focus from the teacher to empirical evidence, meaning that after explaining certain basic concepts, classroom dialogues and interpretations should revolve around empirical data. In this model, the role of the teacher is neither eliminated nor diminished; rather, the teacher functions as a guide and interpreter of the paradigm, responsible for initially conveying concepts and skills and then directing the interpretation of phenomena.

The framework developed in this paper suggests that although established approaches—such as Guided Discovery Learning (Bruner, 1961; Mayer, 2004) and Scaffolded Inquiry (Wood, Bruner, & Ross, 1976; Quintana et al., 2004; Bell et al., 2005)—provide powerful mechanisms for supporting students' engagement in scientific reasoning, they often operate without an explicit philosophical account of why balancing guidance and autonomy is pedagogically essential. A Kuhnian perspective (Kuhn, 1996) offers such an account by demonstrating that scientific inquiry always unfolds within a paradigm that simultaneously enables and constrains problem solving. Interpreting instructional guidance through this lens situates scaffolding and structured discovery within the broader logic of scientific practice, thereby enriching the theoretical foundations of these pedagogical models. Rather than replacing existing approaches, the proposed framework complements them by offering a deeper conceptual rationale that can inform future research on inquiry-based science education, curriculum design, and the teaching of the nature of science (Duschl & Grandy, 2013).

Our proposed pedagogical approach has been developed and examined specifically within the context of physics. Whether this model can be effectively extended to other disciplinary areas remains an open question. We just wanted to let you know that we note here only a key consideration that points toward a productive direction for future research. The epistemological structure of physics—characterized by relatively strong conceptual coherence and the presence of widely shared paradigmatic frameworks—differs markedly from that of many other fields. Because our approach draws on the notion that science education involves enabling learners to inhabit and work within a paradigm's conceptual structure, its applicability outside disciplines with similar levels of conceptual consolidation is uncertain. In domains where multiple, coexisting, and sometimes competing frameworks shape inquiry, the absence of a single dominant paradigm may limit the straightforward transferability of our model. Future research should therefore investigate how the core principles of the proposed approach might be adapted, reinterpreted, or reconfigured for disciplines that do not exhibit the same degree of paradigmatic unity as physics. Careful examination of these disciplinary differences will be essential for determining the scope and boundaries of the approach's broader applicability.

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