

Bridging Indian Knowledge Traditions and Modern Physics: A Critical Framework for Interdisciplinary Inquiry

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Abstract

The growing institutional interest in Indian Knowledge Systems (IKS) has reopened a difficult but productive question: how should premodern Indian accounts of matter, motion, space, causality, number, astronomy and observation be placed in conversation with modern physics without collapsing historical differences or promoting retrospective claims of scientific priority? This article develops a critical framework for such interdisciplinary inquiry. It is a conceptual and evidence-informed study based on established scholarship in the history and philosophy of Indian science, classical Nyaya-Vaisesika thought, Indian mathematical astronomy, the Kerala mathematical tradition, and contemporary philosophy of science. Rather than claiming that ancient Indian categories are identical to quantum mechanics, relativity or particle physics, the paper distinguishes six possible relations between knowledge traditions: historical precursor, structural analogy, heuristic resonance, independent convergence, substantive incompatibility, and unsupported retrospective projection. Selected cases—Vaiśeṣika atomism and categories of substance and motion; Indian mathematical astronomy; Kerala power-series mathematics; and observer-related epistemology—are examined through this lens. The analysis shows that Indian traditions contain sophisticated conceptual, mathematical and observational practices that deserve historically responsible study, but their scientific significance is best established through philology, contextual history, mathematical reconstruction and empirical validation rather than similarity of vocabulary. An interdisciplinary research protocol is proposed for physics education and IKS scholarship. The framework supports plural intellectual history while preserving the methodological standards that make modern physics experimentally testable and cumulatively revisable.

1. Introduction

The relationship between inherited knowledge traditions and modern science has become a significant issue in higher education. In India, the National Education Policy 2020 and subsequent University Grants Commission initiatives have encouraged systematic engagement with Indian Knowledge Systems across disciplines. The policy opportunity

is intellectually valuable, but it also creates a methodological responsibility. Bringing classical Indian ideas into a physics classroom cannot mean treating every philosophical resemblance as a scientific equivalence. Equally, the history of science should not be narrated as though mathematically sophisticated and observational traditions outside early modern Europe were merely peripheral.

Indian intellectual history contains several traditions relevant to questions now associated with the physical sciences. Nyaya and Vaisesika developed detailed ontologies of substances, qualities, motion, inherence, causation and inference. Astronomical schools produced computational models for planetary phenomena, calendars and trigonometric procedures. Medieval Kerala mathematicians developed remarkable infinite-series techniques in the service of astronomy. Metallurgical, architectural and technical practices also embodied knowledge of materials and measurement. These achievements are historically significant in their own right; they need not be redescribed as disguised versions of twentieth-century physics in order to be taken seriously.

The central problem is therefore one of comparison. What does it mean to say that two concepts from different intellectual worlds are “similar”? A Sanskrit term translated as atom, space, motion or observation may belong to an ontology, inferential system and purpose unlike those of contemporary physics. Modern physical concepts are embedded in mathematical formalisms, measurement procedures, instrumentation, predictive models and experimental tests. Premodern philosophical categories may instead be embedded in metaphysics, logic, cosmology, linguistic analysis or soteriological concerns. Responsible interdisciplinarity must identify both correspondence and non-correspondence.

This article proposes a critical framework for bridging these domains. Its aim is neither celebratory equivalence nor dismissive separation. It asks how historians, philosophers, physicists and educators can examine Indian knowledge traditions as sources of concepts, questions, methods and historical achievements while maintaining the evidential norms of modern science. The result is intended as a research-oriented framework suitable for higher education and for scholarship at the intersection of IKS, history of science and physics education.

2. Objectives and Research Questions

The study has four objectives:

- I.to identify historically defensible points of contact between selected Indian knowledge traditions and themes relevant to physics;
- II.to distinguish analogy from theoretical identity;
- III.to formulate criteria for evaluating interdisciplinary claims;
- IV.to propose a research and pedagogical framework that encourages critical inquiry rather than unverified equivalence.

The guiding questions are:

- I. What kinds of evidence are required before a classical Indian concept can be compared with a modern physical concept?
- II. Which examples provide strong historical or mathematical grounds for comparison?
- III. Where do popular comparisons exceed the evidence?
- IV. How can IKS be integrated into physics education without weakening either historical scholarship or scientific method?

3. Method and Scope

This is a critical conceptual review, not a report of newly collected experimental data. The evidence base consists of primary-text scholarship and established secondary literature in the history of Indian mathematics and astronomy, Indian philosophy, and philosophy of science, together with official higher-education guidance on IKS. Priority is given to works that reconstruct texts, chronology, mathematical procedures and philosophical arguments. The article deliberately avoids fabricating numerical datasets or presenting interpretive comparisons as empirical discoveries.

Four domains are used as analytical cases: Nyaya–Vaisesika accounts of matter and motion; Indian mathematical astronomy; the Kerala School's infinite-series mathematics; and epistemological discussions of observation and inference. These cases were selected because they permit different levels of comparison—ontological, mathematical, observational and methodological. Claims are evaluated through source provenance, conceptual precision, mathematical structure, empirical content, historical transmission and falsifiability.

The word “Indian” is used here as a broad civilizational and historiographical descriptor, not as a claim that Indian knowledge was homogeneous. Sanskrit Brahmanical traditions, Buddhist and Jain intellectual cultures, regional mathematical schools, Islamic scholarly exchanges and artisanal practices interacted in complex ways. A credible IKS framework must therefore remain plural and historically situated rather than presenting a single timeless system.

4. Why Interdisciplinary Comparison Is Difficult

Interdisciplinary comparison is attractive because it can reveal neglected intellectual possibilities, but it is vulnerable to anachronism. Anachronism occurs when a later concept is projected backward into a text whose authors did not possess the later theory, evidence or mathematical apparatus. Calling a classical indivisible entity a “quark,” for example, would require much more than both being described as minute constituents. Quarks are defined within quantum field theories, possess specific quantum numbers, participate in gauge interactions and are inferred through a large experimental and mathematical structure. A classical atom belongs to a different explanatory system.

Translation introduces a second difficulty. Terms such as paramanu, akasa, dik, guṇa, karma and pramāṇa have technical meanings within particular philosophical traditions. Their English renderings—atom, ether/space,

atom of nineteenth-century chemistry, the quantum-mechanical atom, and the Standard Model's elementary particles are not equivalent even to one another; each belongs to a different stage of physical theory. It would therefore be still less defensible to identify Vaiśeṣika paramāṇus directly with electrons, photons or quarks.

A more fruitful comparison concerns explanatory structure. Vaisesika asks what kinds of entities must be posited to explain stable qualities and transformations in experienced objects. Modern physics likewise employs unobservable theoretical entities, but their acceptance depends on quantitative predictions and converging experimental evidence. The pedagogical value lies in comparing forms of inference: what warrants belief in an entity that cannot be directly seen? Students can contrast inference from macroscopic qualities in classical philosophy with contemporary inference from tracks, spectra, scattering distributions and detector signals.

Motion provides another useful bridge. Vaisesika classified forms of karma and considered causal conditions for changes in physical objects. Modern mechanics, by contrast, represents motion through mathematically defined variables and dynamical laws. The historical comparison can therefore illuminate a transition from qualitative taxonomy to mathematical dynamics. It should not be described as though classical categories already contained Newtonian mechanics or relativity.

6. Case II: Mathematical Astronomy as a Stronger Bridge

Indian mathematical astronomy offers a stronger basis for comparison because its claims are expressed through explicit computational procedures. Siddhāntic traditions dealt with calendrical calculation, planetary positions, eclipses, trigonometric quantities and observational correction. Historians have shown that these traditions were neither isolated nor static; they developed through internal innovation and exchanges across Greek, Persian, Arabic and other scholarly worlds. Al-Biruni's eleventh-century account is particularly valuable because it documents Indian astronomical and mathematical literature from the perspective of a learned external observer while also engaging critically with its concepts.

Here the relevant bridge to physics is not a claim that premodern astronomy possessed modern astrophysics. It is the continuity of scientific practices: modelling periodic phenomena, computing predictions, comparing calculations with observations, revising parameters and transmitting algorithms. These practices demonstrate that mathematical engagement with nature has multiple historical lineages. They also show why astronomy often becomes a meeting point between mathematics, observation and physical explanation.

For contemporary teaching, an historical astronomical algorithm can be reconstructed and compared with a modern numerical model. Students may examine what was being predicted, what observations were available, how error was handled and what assumptions were built into the model. Such work produces a genuine interdisciplinary exercise because the historical object remains intact while modern tools are used to analyse its performance.

7. Case III: The Kerala School and Infinite Series

The Kerala mathematical tradition provides one of the clearest examples of a historically demonstrable achievement relevant to the mathematical foundations of physics. Scholarship on Madhava and later authors such as Nilakantha and Jyēṣṭhadeva has documented infinite-series expansions associated with trigonometric functions and π . The Yuktibhasa is particularly important because it preserves reasoning and demonstrations rather than only computational rules. Modern historians of mathematics have reconstructed these procedures and situated them within the astronomical needs of the Kerala tradition (Plofker, 2009; Roy, 2011).

The responsible claim is significant enough without exaggeration: sophisticated infinite-series methods were developed in Kerala before the seventeenth-century European development of calculus. The historical literature does not establish a direct line of transmission from Kerala to Newton or Leibniz, and priority should not be confused with influence. This distinction is essential for a Scopus-level interdisciplinary argument because it separates documented mathematics from speculative diffusion narratives.

The connection to physics is indirect but powerful. Modern mechanics, electrodynamics, quantum theory and relativity depend heavily on calculus, differential equations, series approximations and numerical analysis. Kerala mathematics therefore offers an excellent case for showing that some mathematical tools foundational to modern physics have a richer global history than conventional textbook narratives imply. The educational bridge is mathematical reconstruction, not retrospective relabelling.

8. Observation, Inference and the ‘Observer’ Problem

Comparisons between Indian philosophy and quantum physics frequently invoke the “observer.” This is also one of the areas most vulnerable to overstatement. Indian epistemological traditions analysed perception, inference, testimony, error and the conditions under which cognition counts as knowledge. Nyaya in particular developed highly articulated accounts of pramāṇas and inferential reasoning. Such work is relevant to philosophy of science because scientific knowledge also depends on observation, inference and warranted belief.

Quantum mechanics, however, uses “measurement” in a technical physical and mathematical sense. The measurement problem concerns the relationship among quantum states, observables, probabilities, interactions and definite outcomes under competing interpretations of the theory. It is not established merely by noting that a conscious observer appears in some philosophical discussions. Claims that ancient Indian philosophy “anticipated quantum mechanics” therefore require careful qualification.

A defensible bridge is epistemological rather than identificatory. Classical Indian debates can be used to ask how observations become evidence, how instruments extend perception, what role inference plays in establishing unobservable entities, and how theory affects the interpretation of data. These are live questions in philosophy of

physics. The Indian material can enrich the conceptual repertoire through which they are discussed without being presented as an alternative derivation of quantum formalism.

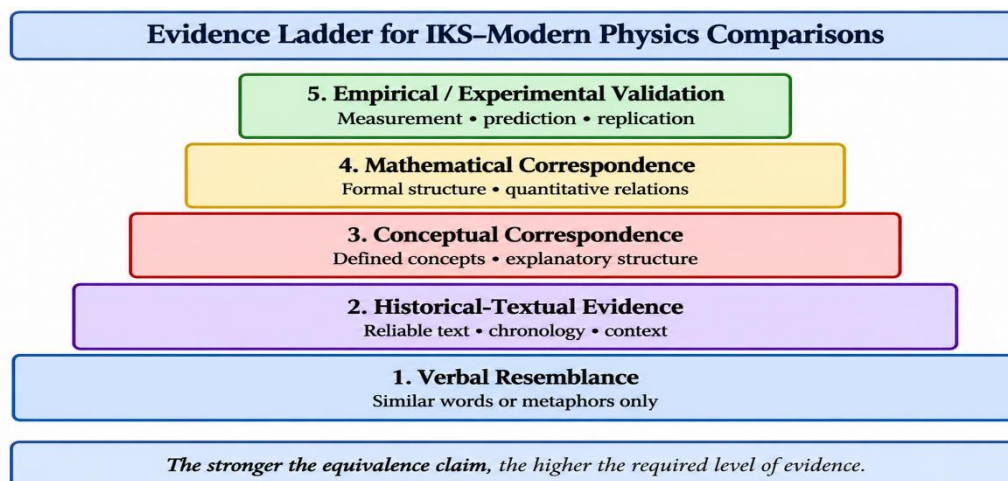


Figure 2. Evidence ladder for evaluating claims that connect Indian knowledge traditions with modern physics.

Source: Author's conceptual synthesis.

9. A Taxonomy of Legitimate and Illegitimate Comparisons

Relationship	Meaning	Example / caution
Historical precursor	An earlier, documented development relevant to a later field, without assuming direct transmission.	Kerala infinite-series mathematics is historically prior to European calculus developments; direct transmission is not thereby proven.
Structural analogy	Two systems share a pattern of explanation but differ in theory and evidence.	Classical atomism and modern microphysical explanation both analyse composites, but their entities and validation differ.
Heuristic resonance	An older concept stimulates questions or alternative conceptual framing.	Pramāṇa theory can enrich discussion of evidence and inference in science.
Independent convergence	Similar solutions emerge in distinct traditions under comparable problems.	Comparable computational concerns may arise in astronomy without implying borrowing.
Substantive incompatibility	The systems make claims that cannot both be retained under the same evidential framework.	A metaphysical category may lack measurable variables required by a physical theory.
Retrospective projection	Modern terminology is read into an old text without textual, mathematical or empirical support.	Equating paramāṇu with a specific Standard Model particle solely from verbal similarity.

Table 1. Taxonomy for critical comparison across knowledge traditions. Source: Author's synthesis.

10. The Proposed Six-Stage Research Protocol

A rigorous interdisciplinary project should proceed through six stages. First, identify the source claim in a reliable edition or scholarly translation rather than through quotations circulating online. Second, establish chronology,

authorship where possible, genre and intellectual context. Third, reconstruct the source concept in its own technical vocabulary. Fourth, specify the modern physics concept with equal precision, including its mathematical and experimental commitments. Fifth, compare similarities and differences at the levels of ontology, mathematics, prediction and evidence. Sixth, classify the relationship using the taxonomy above. Only after these steps should broader philosophical or educational implications be drawn.

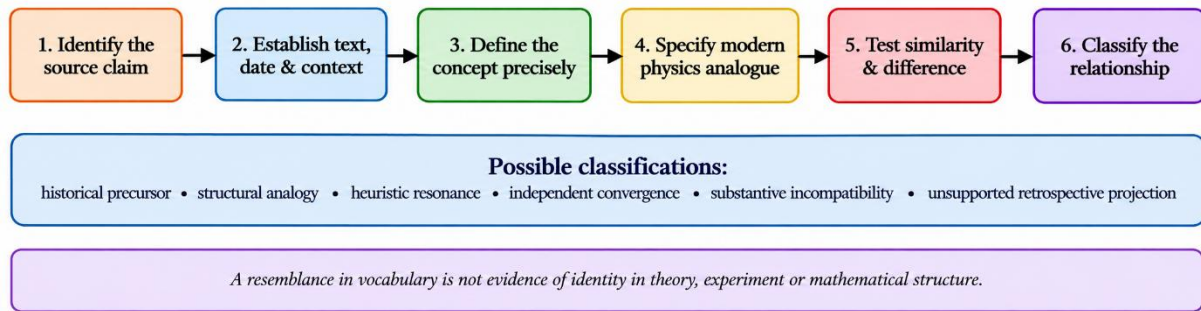


Figure 3. Six-stage protocol for evaluating cross-traditional scientific comparisons. Source: Author's conceptual synthesis.

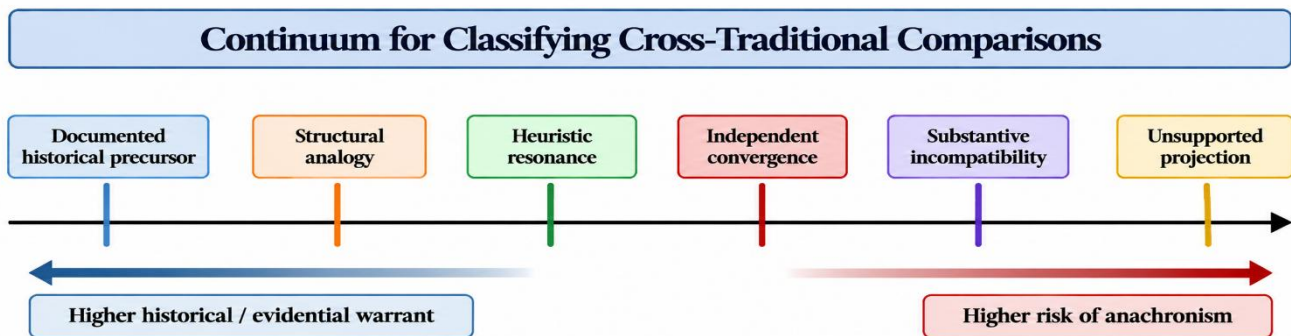


Figure 4. Continuum for classifying cross-traditional comparisons from documented historical relationship to unsupported retrospective projection. Source: Author's conceptual synthesis.

11. Scientific Validation and the Limits of Textual Evidence

Textual evidence can establish what a historical author argued, but it cannot by itself establish whether a physical claim is true. If a traditional source contains a proposition that can be operationalised as a measurable physical hypothesis, contemporary validation requires appropriate experiment, controls, uncertainty analysis, reproducibility and peer scrutiny. The standards should not be relaxed because a claim is culturally valued, nor should a claim be rejected merely because it is old. Symmetrical methodological scrutiny is the fairest form of intellectual respect.

This principle is especially important in areas where IKS is presented as “science.” Historical scholarship, philosophical interpretation and experimental science answer different questions. A historian may establish that a technique existed in a certain period; a philosopher may clarify its conceptual coherence; a physicist may test a quantitative implication. Strong interdisciplinary work makes these evidential layers explicit.

The UGC's IKS initiatives create a useful institutional space for such work, but integration should be accompanied by methodological training. Students need to learn source criticism, translation awareness, basic historiography and the logic of scientific testing. Without these safeguards, curricular inclusion can drift toward lists of achievements or unsupported equivalence. With them, IKS can become a demanding form of interdisciplinary scholarship.

12. Implications for Physics Education

A critical IKS–physics interface can improve physics education in at least four ways. First, it can broaden the history of science and show that mathematical and observational inquiry developed in multiple cultural settings. This helps students see science as a human enterprise shaped by problems, institutions, instruments and exchanges rather than as a sequence of isolated European discoveries.

Second, historical comparison can sharpen conceptual understanding. Asking why a Vaiśeṣika atom is not the same as a quantum particle forces students to articulate what makes a modern particle concept scientifically specific. They must refer to mathematical properties, experimental signatures and theoretical relations rather than relying on a dictionary definition. Difference becomes pedagogically productive.

Third, reconstructed historical problems can support inquiry-based learning. Students can compute a trigonometric series, compare convergence, reproduce an astronomical calculation, or map an inferential argument. These activities connect history with mathematics and physics while producing assessable learning outcomes.

Fourth, the approach can strengthen scientific literacy by teaching students to distinguish evidence from analogy. In an information environment where spectacular historical claims circulate rapidly, the ability to ask “What is the source?”, “What exactly does the term mean?”, “What prediction follows?”, and “What evidence would discriminate the claim?” is a core scientific competence.

13. A Model for Interdisciplinary Classroom and Research Practice

Activity	IKS material	Physics / science task	Expected outcome
Concept reconstruction	Selected Vaisesika categories	Compare with operational definitions in mechanics/matter physics	Recognise analogy versus identity
Mathematical reconstruction	Kerala trigonometric series	Calculate approximations and error/convergence	Connect history with mathematical methods
Astronomical modelling	Siddhantic computational procedure	Compare prediction, parameters and observation	Understand models as historically situated tools
Epistemology seminar	Nyaya accounts of perception/inference	Analyse evidence for unobservable entities	Strengthen philosophy-of-science reasoning
Claim audit	Popular IKS–physics comparison	Trace source and test evidential support	Develop source criticism and scientific literacy

Table 2. Suggested applications of the critical framework in higher education.

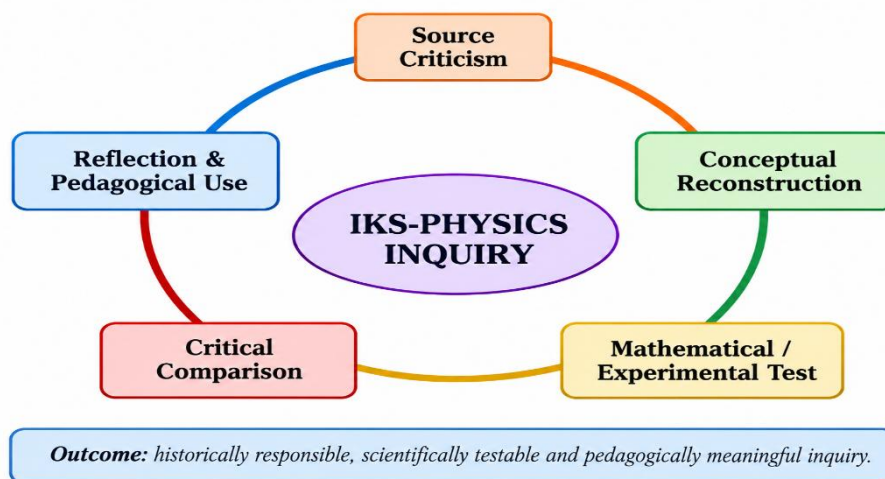


Figure 5. Iterative IKS-physics inquiry cycle for research and higher-education practice. Source: Author's conceptual synthesis.

14. Discussion

The cases considered here reveal a spectrum rather than a single relationship between Indian knowledge traditions and modern physics. Kerala series mathematics offers a strong historically documented bridge because mathematical procedures can be reconstructed and compared. Indian astronomy offers a strong methodological bridge through modelling, calculation and observation. Nyaya–Vaisesika offers a rich conceptual bridge, particularly for ontology, causation and inference, but its categories cannot be equated with modern microphysics without major distortion. Observer-centred comparisons with quantum theory are most useful at the level of epistemological questions and least reliable when framed as claims of theoretical anticipation.

This spectrum suggests that interdisciplinary quality depends on the type of evidence available. The closer a claim comes to asserting scientific equivalence, the stronger the required mathematical and empirical evidence. Conceptual resonance requires less, but it must be labelled as resonance. Historical priority requires secure chronology and textual reconstruction. Influence requires evidence of transmission. Scientific validity requires empirical support. These distinctions provide a simple defence against both triumphalism and Eurocentric dismissal.

The framework also changes what “bridging” should mean. A bridge does not erase the banks it connects. The intellectual value of classical Indian traditions partly lies in their difference from modern disciplinary arrangements. Nyaya’s concern with warranted cognition, Vaisesika’s categorical ontology and siddhantic astronomy’s computational practices arose within distinctive goals and institutions. Treating them only as incomplete modern physics would paradoxically diminish their historical originality.

At the same time, insisting on historical difference should not become a reason to quarantine traditions from contemporary inquiry. Mathematical reconstructions can be computationally tested; material practices can be experimentally analysed; philosophical arguments can be compared with contemporary debates about realism,

causation and evidence. The most productive scholarship therefore combines historical fidelity with present-day analytical tools while being explicit about which questions belong to which discipline.

15. Limitations and Future Research

The article is selective. It does not attempt a comprehensive history of Indian science, nor does it cover Buddhist theories of momentariness, Jain cosmology, classical acoustics, optics, metallurgy, architecture or later Indo-Persian scientific exchanges in detail. Future work should include specialists in Sanskrit and regional languages, historians of science, philosophers and practising physicists. Digital critical editions and computational reconstructions could enable transparent replication of historical calculations. Experimental projects concerning traditional materials or technologies should be preregistered where appropriate and should report null results as readily as positive ones.

A further research priority is educational evaluation. Courses using the proposed framework could be studied for their effects on conceptual understanding, epistemic cognition, historical reasoning and resistance to misinformation. Such research would move IKS integration from policy aspiration to evidence-based pedagogy.

16. Conclusion

Indian knowledge traditions and modern physics can be placed in a serious and mutually illuminating conversation, but only when comparison is disciplined by history, language, mathematics and evidence. The strongest scholarship does not need to claim that classical Indian thinkers already possessed quantum mechanics, relativity or particle physics. Their documented achievements—in logical analysis, ontology, mathematical astronomy and infinite-series reasoning—are substantial enough to merit study on their own terms.

The critical framework developed in this article replaces the binary choice between glorification and dismissal with a graded taxonomy of relationships. Historical precursor, structural analogy, heuristic resonance, independent convergence, incompatibility and retrospective projection are analytically different claims and require different kinds of evidence. The proposed six-stage protocol makes these distinctions operational for researchers and teachers. For contemporary higher education, the central opportunity is therefore not to turn IKS into a catalogue of modern discoveries supposedly hidden in ancient texts. It is to use India's plural intellectual traditions to deepen questions about matter, measurement, inference, mathematical modelling and the history of scientific reasoning. Such an approach can decolonise the history of science without abandoning scientific standards, and it can enrich physics education without confusing cultural significance with experimental proof. That balance is the foundation of a credible interdisciplinary inquiry.

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