CHAPTER 8

GENERATİVE AI (GENAI) İN SCİENCE EDUCATİON AS AN INNOVATİVE PRACTİCE: A SYSTEMATİC REVİEW

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Abstract

Generative artificial intelligence (GenAI)—particularly large language model (LLM) tools—has rapidly entered educational practice and is beginning to reshape science teaching, learning, and assessment. Science education is a distinctive use case because it requires epistemic reliability: learners must justify claims with evidence, apply disciplinary constraints (e.g., units, conservation laws), and engage in inquiry practices. This chapter offers a PRISMA 2020–aligned systematic review of recent research on GenAI in science education, complemented with a policy and ecosystem analysis for India. Evidence from published systematic reviews and empirical studies suggests that GenAI can support explanation, scientific writing, formative feedback, and inquiry planning when embedded in well-designed tasks. However, risks persist: hallucinations and inaccuracies, bias, privacy concerns, and academic integrity threats, especially where institutional guidance is limited. In India, NEP 2020 and NCF-SE 2023 emphasize competency-based learning, technology integration, and scientific temper, while national digital infrastructure (DIKSHA and NDEAR) provides a scalable platform for teacher professional development and content delivery. This chapter synthesizes evidence into an India-ready implementation framework (S-CIENTIFIC), proposes assessment redesign options, and provides classroom-ready prompt templates, rubrics, and a reproducible search strategy (databases and Boolean strings).

Keywords: *Generative AI, Large Language Models, Science Education, Systematic Review, İnquiry Learning, AI literacy, NEP 2020, NCF-SE 2023, DIKSHA, NDEAR, IndiaAI Mission.*

Introduction

Science education aims to cultivate scientific temper, conceptual understanding, evidence-based reasoning, and the ability to investigate phenomena. These aims require learners to move beyond memorization toward explanation, modeling, and argumentation. In this landscape, GenAI has emerged as a disruptive yet potentially empowering innovation. LLM-based tools can generate natural-language explanations, questions, summaries, and feedback; they can also help learners draft laboratory reports, compare alternative models, generate code for basic data analysis, and translate technical language into accessible forms. Systematic reviews of ChatGPT and related

GenAI tools in education report perceived benefits such as immediate feedback, personalization, and improved access to learning support, especially for writing-intensive tasks *(Bettayeb & Abu Talib, 2024).*

At the same time, science education is a demanding domain for GenAI because scientific knowledge is constrained by evidence, measurement, and formal principles. GenAI outputs may be fluent yet incorrect (hallucinations'), potentially reinforcing misconceptions if used without verification routines. Systematic reviews of GenAI in pedagogical practices highlight recurring concerns: inaccuracies, bias, threats to academic integrity, and uncertainty about how GenAI changes learners' cognitive effort and metacognition (Wang et al., 2025). These concerns have motivated international guidance calling for human-centered, safe, equitable, and age-appropriate adoption of GenAI in education *(UNESCO, 2023).*

The Indian education context creates both opportunities and constraints for GenAI adoption. NEP 2020 emphasizes technology integration and explicitly states that technology interventions should be rigorously and transparently evaluated in relevant contexts before scaling (Ministry of Education, 2020). India also has large-scale digital education infrastructure through DIKSHA, a national platform offering curriculum-aligned digital content and teacher professional development across languages *(DIKSHA, 2026; Digital India, 2026).* Complementing DIKSHA, the National Digital Education Architecture (NDEAR) provides a unifying, interoperable framework to connect education services and platforms while emphasizing privacy and security by design *(Ministry of Education, 2022).*

The National Curriculum Framework for School Education *(NCF-SE)* 2023 operationalizes NEP 2020's competency-based vision and includes subject guidance for science education across stages *(Ministry of Education, 2023).* In the school sector, CBSE has introduced Artificial Intelligence as a skill subject *(e.g., Subject Code 417)* and developed manuals for AI integration across subjects, including science *(CBSE, 2024a; CBSE, 2020).* These developments indicate that India is building curricular and infrastructural readiness for AI-related learning. However, learning about AI' (AI literacy and skills) is distinct from 'learning with GenAI' (using LLM tools to support learning in other subjects).

Given the rapid diffusion of GenAI tools outside institutional control, science educators and policymakers face urgent questions: What does research evidence say about GenAI's impact on science learning? Which classroom uses are beneficial, which are risky, and under what conditions? How can Indian schools and HEIs adopt GenAI in ways that align with NEP 2020 and NCF-SE 2023 while protecting privacy, equity, and academic integrity? This chapter addresses these questions through a systematic review and an India-focused synthesis.

Conceptual Background: Why Science Education is a Distinctive GenAI Use Case

GenAI tools are general-purpose: they can generate coherent text and respond conversationally across topics. In science education, however, quality is not simply readability; it is epistemic warrant. Learners must justify claims with data, apply constraints (units, conservation laws, boundary conditions), and evaluate alternative explanations. Therefore, GenAI can be educationally powerful only when it is embedded in tasks that preserve learner agency and require verification. UNESCO's guidance emphasizes ethical validation, protection of privacy, and human-centered pedagogical design *(UNESCO, 2023).*

From a learning sciences perspective, GenAI can be positioned as (a) a cognitive scaffold that prompts explanation, reflection, and revision; (b) a 'second voice' that offers alternative hypotheses and representations; or (c) an automated answer generator that may reduce productive struggle. The literature suggests that outcomes depend strongly on task design and teacher mediation. Reviews in pedagogy report benefits when GenAI is used as a supplementary tool for feedback and idea generation but warn against overreliance and reduced critical thinking if students outsource reasoning *(Wang et al., 2025).*

In India, science education priorities include developing scientific temper, inquiry, and application of knowledge to local and national challenges. NCF-SE 2023 frames science learning as building process skills such as observation, analysis, inference, and evidence-based thinking, aligning with broader aims of NEP 2020 (Ministry of Education, 2023). Responsible GenAI integration can support these goals—for example, by generating prompts for data interpretation, proposing alternative models to critique, or helping students express scientific reasoning in their home language. However, equitable access and language performance differences must be considered to avoid widening learning gaps.

Methods: PRISMA 2020–Aligned Systematic Review Approach

This chapter follows PRISMA 2020 reporting principles to transparently describe the review purpose, methods, and synthesis approach (Page et al., 2021). Because research on GenAI in science education is recent and heterogeneous, the review uses a narrative thematic synthesis rather than a quantitative meta-analysis. The review is complemented by a policy and ecosystem scan for India *(NEP 2020, NCF-SE 2023, DIKSHA, NDEAR, CBSE AI initiatives, and the IndiaAI Mission).*

Research questions guiding the review were: (RQ1) What are the dominant GenAI use cases in science education (teaching, learning, assessment, inquiry)? (RQ2) What outcomes are reported (learning, engagement, scientific writing, reasoning quality)? (RQ3) What risks and challenges are documented (accuracy, bias, integrity, privacy, equity)? (RQ4) What implementation conditions enable responsible, effective use (AI literacy, prompt design, verification routines, governance)?

Search strategy overview. A reproducible search strategy (databases and Boolean strings) is provided in Addendum C. Recommended databases for peer-reviewed studies include Scopus, Web of Science, ERIC, and Google Scholar, with optional inclusion of IEEE Xplore/ACM for STEM intersections. Policy sources include UNESCO, OECD, and Indian education policy/curriculum documents *(UNESCO, 2023; OECD, 2023; Ministry of Education, 2020; Ministry of Education, 2023).*

Eligibility criteria. Included works were: (a) peer-reviewed empirical studies, design-based research, or systematic reviews; (b) studies involving GenAI/LLM tools used for teaching/learning/assessment in science or STEM; (c) studies reporting outcomes, user perceptions, or implementation insights. Excluded works were: purely technical model papers without educational context; opinion pieces without methods; and non-education applications.

Synthesis. Included studies were coded by education level, science discipline, GenAI task type (explanation, writing, inquiry, assessment), reported outcomes, risks, mitigation strategies, and contextual factors (policy, access, training). Themes were developed iteratively and reported as a narrative synthesis.

PRISMA 2020 FLOW DIAGRAM

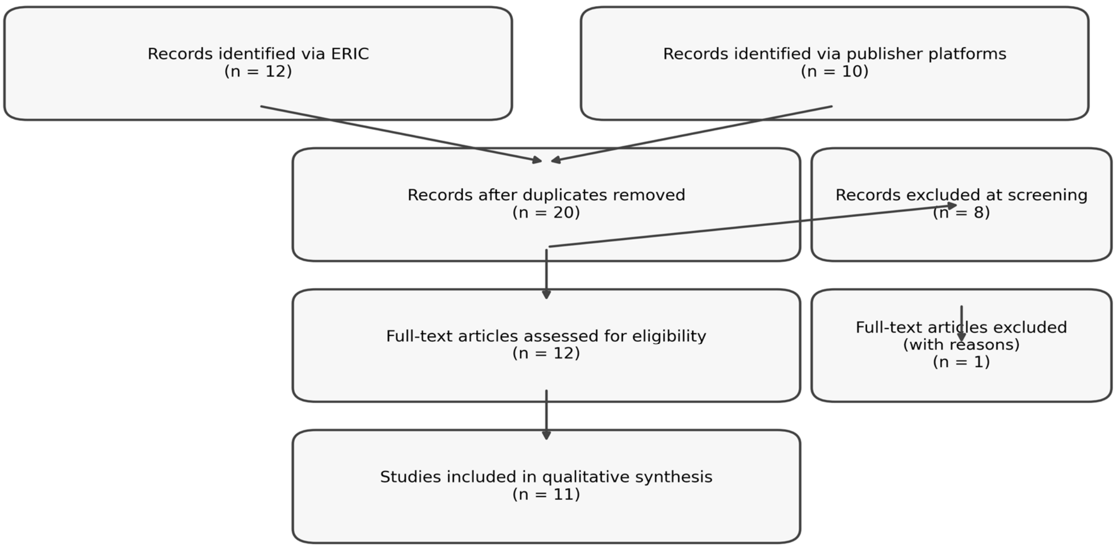

Figure 1. PRISMA 2020 flow diagram

Results: Thematic Synthesis of Evidence on GenAI in Science Education

GenAI for explanation, concept clarification, and tutoring

A dominant use case is employing GenAI as an on-demand explanation partner. Learners ask conceptual questions (e.g., chemical equilibrium, Newton's laws, genetics) and receive conversational explanations, examples, and analogies. Systematic reviews report benefits such as rapid access to information, personalized responses, and improved learning support—particularly for learners seeking clarification outside classroom time *(Bettayeb & Abu Talib, 2024).*

However, GenAI responses can be inaccurate or overconfident. In science education, errors may involve incorrect causal mechanisms, misapplied formulas, or misunderstandings of experimental design. Effective practice requires a 'verification layer': students compare GenAI responses against textbooks, teacher notes, simulations, or laboratory data. UNESCO's guidance recommends ethical validation and human supervision to ensure safe, meaningful use *(UNESCO, 2023).*

GenAI for scientific writing, lab reports, and communication

GenAI is frequently used to support scientific writing: organizing lab reports, refining grammar, and providing formative feedback. Reviews of GenAI in pedagogy report improved instructional efficiency through faster feedback and personalized materials, alongside perceived gains in engagement *(Wang et al., 2025).* For science education, writing support is beneficial when it helps students express reasoning clearly, but becomes problematic when GenAI replaces the student's scientific thinking.

A practical distinction is between language-level assistance (clarity, structure) and reasoning-level outsourcing (inventing results, fabricating interpretations). Reviews highlight academic integrity concerns *(Bettayeb & Abu Talib, 2024).* Process-oriented assessment designs—raw data submission, drafts, GenAI logs, and oral defence—help preserve authenticity while still leveraging GenAI for revision.

GenAI for inquiry: hypothesis generation and experimental planning

Emerging work explores GenAI for inquiry-based science learning: brainstorming hypotheses, identifying variables, planning procedures, and anticipating sources of error. Syntheses suggest GenAI can catalyze idea generation and support problem-solving when used as a guided tool *(Wang et al., 2025).* The highest value often comes from prompting learners to consider alternatives, justify choices, and identify confounds, rather than producing a single 'best' answer.

In India, inquiry tasks can be strengthened by contextualizing science in local phenomena (e.g., water quality, heat waves, air pollution, agriculture, biodiversity). GenAI can help teachers generate locally relevant question sets and data-collection templates, while students still conduct observation and measurement. Safety remains essential: experimentation must stay within teacher-approved, age-appropriate protocols.

Assessment pressures: integrity, authenticity, and redesign

Assessment is consistently identified as a pressure point. Reviews report concerns that students may submit AI-generated work as their own, undermining authenticity and fairness *(Bettayeb & Abu Talib, 2024; Wang et al., 2025)*. In response, educators are shifting toward assessment designs that emphasize reasoning processes, data interpretation, and oral explanation—outcomes that are more difficult to outsource.

OECD analysis emphasizes the need for trustworthy and equitable digital ecosystems and guardrails around AI use *(OECD, 2023)*. In India, assessment redesign aligns with competency-based approaches in NCF-SE 2023, which emphasizes learning outcomes and process skills *(Ministry of Education, 2023)*. Examples include in-class data analysis tasks, viva voce, lab practicals, and iterative projects requiring evidence logs and reflection.

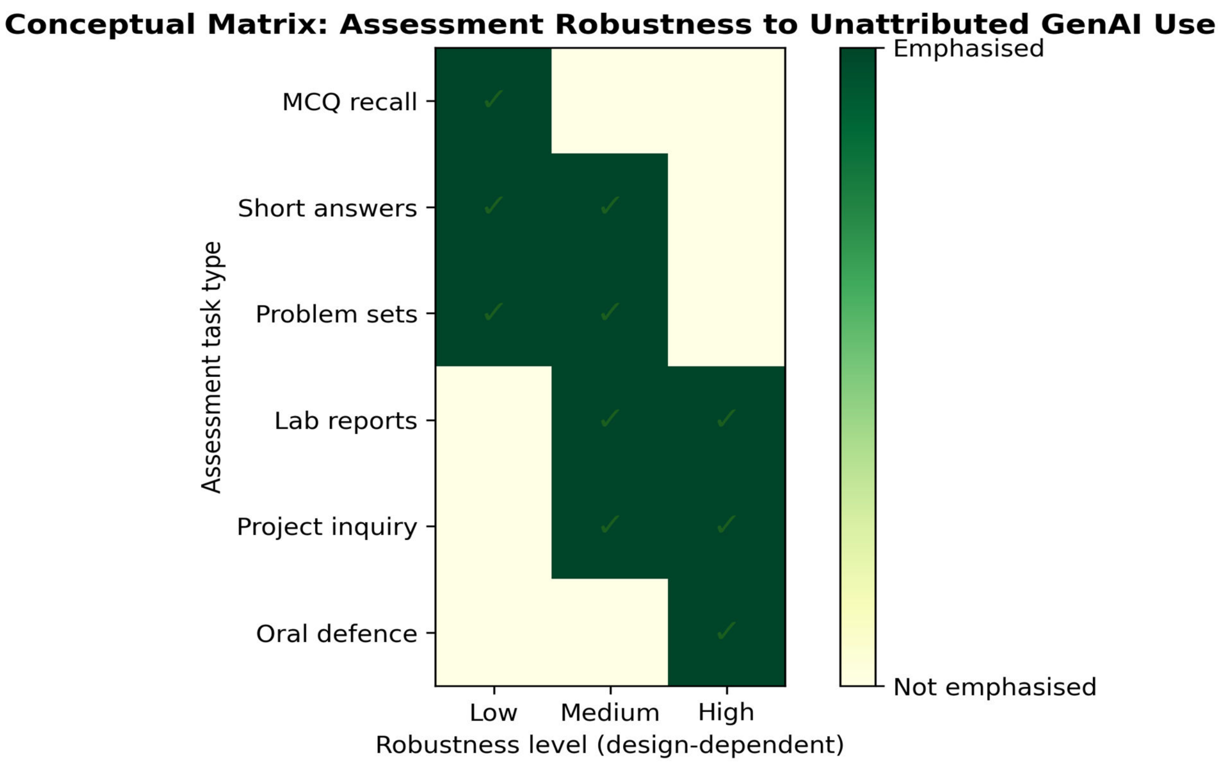

Figure 2. Conceptual matrix of assessment robustness to unattributed GenAI use (design-dependent; illustrative).

AI literacy as a mediator of benefits and harms

Across the literature, AI literacy—understanding what GenAI can and cannot do—emerges as a core mediator. Educational impact depends on instructor guidance, institutional policies, and students' capacity to critically evaluate AI *outputs (Bettayeb & Abu Talib, 2024)*. In science education, epistemic AI literacy' is especially important: students must ask what counts as evidence, what assumptions are present, and how claims could be tested or falsified.

This aligns with NEP 2020's emphasis on critical thinking and ethical awareness around emerging technologies (Ministry of Education, 2020) and UNESCO's human-centered vision *(UNESCO, 2023)*.

Multimodal GenAI and representation translation

GenAI systems are increasingly multimodal, enabling interaction across text, images, and code. In science education, this can support translation among representations—verbal explanation, equations, graphs, and diagrams. Yet multimodal outputs can also embed errors (e.g., wrong axis interpretation, misleading diagrams). Therefore, teachers should explicitly teach checking routines: unit checks, dimensional analysis, constraint checking against physical laws, and comparison with verified sources.

Teacher workload and professional practice

Teachers use GenAI for lesson planning, worksheet generation, and differentiation. Potential efficiency gains are reported, but generated materials must be validated for curricular alignment and scientific accuracy *(Wang et al., 2025)*. In India, DIKSHA can support validation by offering curriculum-aligned resources for cross-checking and by hosting teacher professional development modules on responsible GenAI use *(DIKSHA, 2026)*.

Indian Policy, Curriculum, and Digital Ecosystem

India's policy and infrastructure environment provides several enablers for responsible GenAI adoption in science education. NEP 2020 encourages technology integration while calling for careful evaluation and attention to privacy and ethics *(Ministry of Education, 2020)*. NCF-SE 2023 operationalizes competency-based science learning and recognizes ICT as cross-cutting *(Ministry of Education, 2023)*. DIKSHA provides an at-scale repository of digital resources and teacher professional development *(DIKSHA, 2026)*. NDEAR provides an interoperable architecture with privacy and security by design *(Ministry of Education, 2022)*. Together, these enable an approach where GenAI is integrated through guided pedagogy and verification resources rather than ad hoc, unsupervised use.

CBSE and AI readiness as a bridge to GenAI literacy

CBSE's AI curriculum introduces AI readiness, the AI project cycle, basic Python, and ethical considerations such as bias and access *(CBSE, 2024)*. This 'learning about AI' pathway can be used to support 'learning with GenAI' by making students aware of model limitations and responsible-use expectations.

IndiaAI Mission and indigenous capacity

India AI Mission aims to strengthen India's AI ecosystem through compute capacity, datasets, innovation, applications, future skills, startup financing, and safe and trusted AI (*Press Information Bureau, 2024; IndiaAI, 2026)*. For education, these pillars can support indigenous, multilingual models and governance tools that align better with India's linguistic diversity and curricular priorities, while also enabling teacher training and safe deployment pathways.

Practice Framework for Indian Science Education

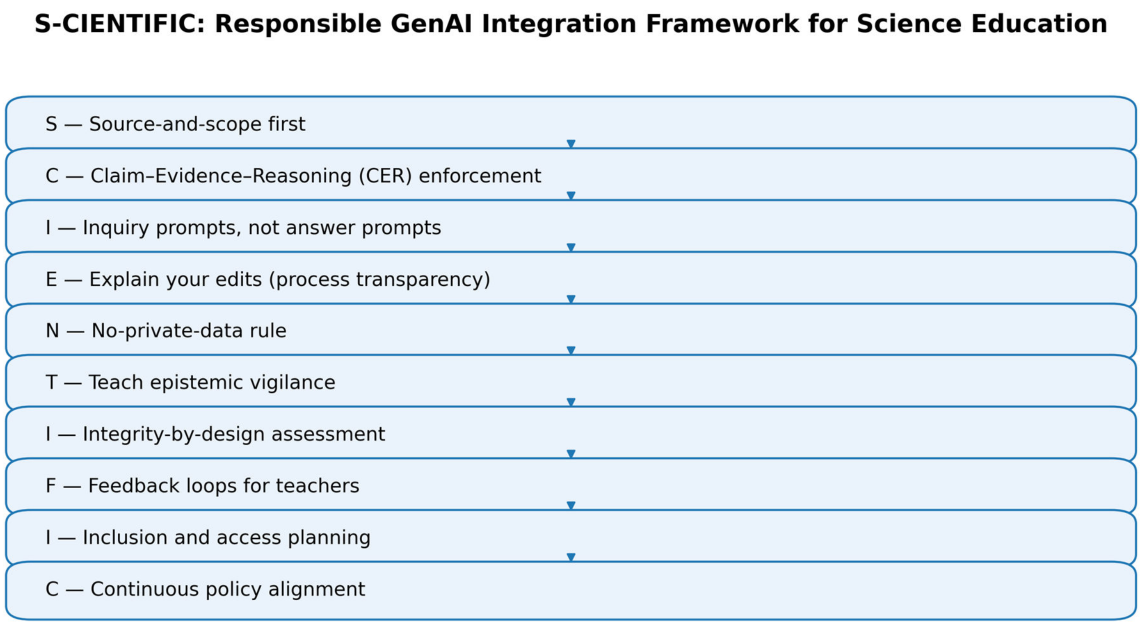

Figure 3. S-CIENTIFIC framework for responsible GenAI integration in science education (proposed in this chapter).

S-CIENTIFIC translates research themes and policy principles into design commitments: (S) Source-and-scope constraints; (C) Claim–Evidence–Reasoning rewriting; (I) Inquiry prompts; (E) Explain edits transparently; (N) No-private-data rule; (T) Teach epistemic vigilance; (I) Integrity-by-design assessment; (F) Feedback loops for teachers; (I) Inclusion and access planning; (C) Continuous policy alignment.

Integrating GenAI into the 5E inquiry cycle

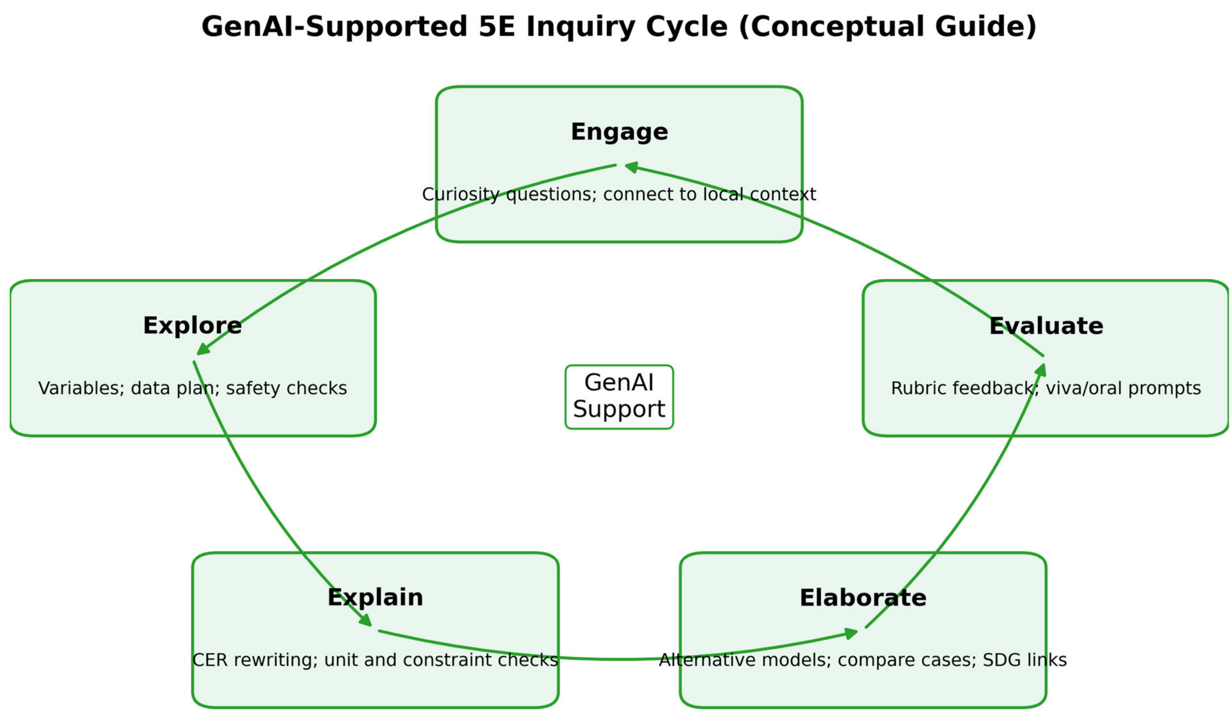

Figure 4. GenAI-supported 5E inquiry cycle

A key principle is to use GenAI to amplify inquiry rather than to shortcut it. In Engage, GenAI can help generate curiosity questions connected to local contexts. In Explore, it can propose variable lists and data-table formats while the teacher enforces safety and feasibility. In Explain, GenAI can help students rewrite explanations into CER form, but students must cite evidence and verified sources. In Elaborate, GenAI can propose alternative models to critique and link concepts to SDGs. In Evaluate, teachers can use GenAI to draft viva questions and feedback prompts, while the teacher remains the final assessor.

Low-bandwidth and multilingual implementation options

Because internet and device access vary, equity-first implementation is essential. Options include: (a) teacher-mediated whole-class GenAI use via projector, (b) rotational station use in computer labs, (c) offline-first verification anchored to DIKSHA resources, and (d) bilingual scaffolding to support comprehension while maintaining scientific precision.

Assessment of redesign options (integrity-by-design)

Assessment redesign can reduce incentives and opportunities for unattributed GenAI use. Options include in-class data tasks, oral defence/viva, lab practicals with observation checks, iterative drafts with process evidence, and reflective prompts that require students to justify decisions. These approaches align with competency-based assessment principles in NCF-SE 2023 and address integrity risks highlighted in the literature.

Tables for Classroom and Policy Implementation

Table 1. GenAI application patterns aligned to Indian curriculum priorities

GenAI use case	Example science task	Science practice supported	Key risk	Indian alignment
Concept clarification	Explain diffusion vs osmosis with local example; identify misconceptions	Explanation, conceptual change	Hallucinations; oversimplification	NCF-SE outcomes; NEP 2020 critical thinking
CER writing support	Rewrite lab conclusion into CER; improve clarity	Scientific communication	Reasoning outsourcing	Competency-based assessment
Inquiry planning	Plan variables/controls for filtration experiment	Inquiry, design	Unsafe/impractical procedures	Experiential learning emphasis
Formative feedback	Rubric feedback on graphs and units	Data literacy	Feedback errors/overreliance	DIKSHA verification and PD
Assessment redesign	Viva questions and reflection prompts	Oral reasoning	Bias/unfairness	Trustworthy governance principles

Note: Tables present design-oriented mappings; they should be adapted to local curricula and resource contexts.

Table 2. Risk–mitigation matrix

Risk	Why it matters	Classroom mitigation	Institutional mitigation
Inaccurate explanations	Misconceptions; wrong causal models	Verification with DIKSHA/NCERT; unit checks	Tool validation; vetted repositories
Academic integrity	Assessment invalidity	Process evidence; viva; in-class tasks	Clear policy; integrity regulations
Data privacy	Student data exposure	No PII; anonymize	Privacy-by-design; procurement controls
Equity/access	Unfair advantage	Group use; offline alternatives	Infrastructure planning; inclusion

Bias/language gaps	Unequal support	Bias detection; multiple sources	Indigenous models; safe & trusted AI

Table 3. Prompt templates with verification

Purpose	Prompt template	Verification output
Misconception check	Explain ____ for Grade __; list 3 misconceptions and corrections; state uncertainty	Corrections cited to DIKSHA/NCERT
CER scaffold	Convert this explanation into Claim–Evidence–Reasoning; do not add data	Evidence linked to data table/graph
Data interpretation	Propose 3 interpretations + 2 confounds; suggest extra data	Chosen interpretation justified with units/error
Inquiry planning	Suggest variables/controls and safe procedure; risk checklist	Teacher-approved procedure + checklist
Viva prep	Generate 10 viva questions incl. why/what-if	Oral answers assessed

Addendum B. Classroom Implementation Examples (Indian Context)

The examples below are aligned with inquiry-oriented, competency-based science learning and can be adapted for different boards and state contexts. They are designed to keep scientific reasoning and evidence at the center while using GenAI only as a scaffold.

Example 1 (Grades 6–8): Local Biodiversity Mini-Inquiry

Topic: Classification, adaptations, ecosystems

Learning objectives:

- Observe and record local biodiversity in/near the school.
- Classify organisms using observable features.
- Write a CER explanation for one adaptation.

Lesson flow (5E-aligned):

- Engage: Generate "I wonder…" questions from campus photos.
- Explore: Field notes (8–10 observations).
- Explain: CER paragraph + evidence from notes.
- Elaborate: Compare two micro-habitats.
- Evaluate: 2-minute viva.

GenAI role (scaffold): GenAI generates field-note template and question prompts; students do not use GenAI to identify species.

Prompt template: "Create a Grade 7 field-note template for biodiversity with columns for observation, evidence, habitat, and classification."

Verification requirement: Students cite at least one DIKSHA/NCERT source for concept definitions.

Assessment idea: Portfolio + viva (integrity-by-design).

Example 2 (Grade 8): Water Filtration and Mixtures

Topic: Separation techniques; mixtures; environmental science

Learning objectives:

- Design a safe filtration procedure.
- Record observations and compare before/after.
- Discuss limitations and improvements.

Lesson flow (5E-aligned):

- Engage: Local water sources discussion.
- Explore: Build filter; collect observations.
- Explain: Graph turbidity proxy + CER.
- Elaborate: Improve design; justify changes.
- Evaluate: Viva + peer review.

GenAI role (scaffold): GenAI used for variable/control brainstorming and safety checklist, under teacher approval.

Prompt template: "Suggest controlled variables, outcomes, and a safety checklist for a school filtration experiment."

Verification requirement: Teacher-approved protocol attached; no unsafe chemical instructions permitted.

Assessment idea: Rubric lab report + transparency appendix.

Example 3 (Grades 9–10): Air Quality Data Reasoning

Topic: PM2.5/AQI trends, graph literacy, confounds

Learning objectives:

- Interpret a dataset; plot graphs with units.
- Propose explanations and confounds.

- Justify with data and references.

Lesson flow (5E-aligned):

- Engage: Provide week-long AQI values.
- Explore: Compute summaries and plot.
- Explain: Hypotheses + confounds list.
- Elaborate: Compare two locations.
- Evaluate: Oral questioning.

GenAI role (scaffold): GenAI generates alternative hypotheses and data needs; students choose and justify.

Prompt template: "Given this time series, propose explanations, confounds, and additional data to strengthen claims."

Verification requirement: Students cite one trusted source (textbook/DIKSHA) for pollution/health concept.

Assessment idea: In-class data task + viva.

Example 4 (Grades 11–12): Equilibrium Error-Checking

Topic: Le Chatelier's principle, constraints-based critique

Learning objectives:

- Predict equilibrium shifts.
- Detect errors in explanations.
- Justify corrections using equations.

Lesson flow (5E-aligned):

- Engage: Equilibrium scenario prompt.
- Explore: Individual prediction then pair compare.
- Explain: Critique AI explanation for errors.
- Elaborate: Create common-error cards.
- Evaluate: Written correction + viva.

GenAI role (scaffold): GenAI provides mixed-quality explanations that students audit.

Prompt template: Teacher: "Generate two explanations (one correct, one subtly incorrect) for equilibrium shift; do not label."

Verification requirement: Students cite definitions for Kc/Kp and justify corrections.

Assessment idea: Marks for error detection + corrected reasoning.

Example 5 (Undergraduate): Lab Report Integrity and Disclosure

Topic: Scientific writing, reproducibility, responsible tool use

Learning objectives:

- Submit raw data and first draft without GenAI.
- Use GenAI only for clarity and structure.
- Defend interpretations orally.

Lesson flow (5E-aligned):

- Draft 1: No GenAI.
- Revision: GenAI for language only.
- Append prompts/outputs and revision rationale.
- Viva to verify understanding and provenance.

GenAI role (scaffold): GenAI used for feedback generation; instructor validates before release.

Prompt template: "Provide rubric-aligned feedback on clarity; do not invent data; flag uncertainties."

Verification requirement: GenAI use statement required; student accountable for accuracy.

Assessment idea: Portfolio + viva; transparency graded.

Addendum C. Search Strategy: Databases, Search Strings, and Screening Workflow

This addendum provides a ready-to-use search strategy to operationalize the PRISMA 2020–aligned approach described in the chapter (Page et al., 2021).

C1. Databases and Information Sources

Recommended academic databases (peer-reviewed literature):

- Scopus
- Web of Science Core Collection
- ERIC
- Google Scholar (supplementary)
- IEEE Xplore / ACM Digital Library (optional)

Recommended policy/grey literature sources (contextual grounding):

- UNESCO guidance on GenAI in education (UNESCO, 2023).
- OECD Digital Education Outlook sections on generative AI governance (OECD, 2023).

- Indian policy/curriculum: NEP 2020; NCF-SE 2023; NDEAR ecosystem policy; DIKSHA resources.
- CBSE AI curriculum and integration manuals (CBSE, 2020; CBSE, 2024a).

C2. Example Boolean Search Strings (copy/paste ready)

Use publication years 2022–present for GenAI/LLM-focused searches, adjusting as needed. Apply language limits only if justified.

Search focus	Example Boolean string
Core GenAI + science education	("generative AI" OR GenAI OR "large language model" OR LLM OR ChatGPT) AND ("science education" OR biology OR chemistry OR physics OR STEM) AND (teaching OR learning OR assessment OR inquiry OR laboratory)
Science writing / lab reports	(ChatGPT OR "large language model" OR LLM OR "generative AI") AND ("lab report" OR "scientific writing" OR "science communication") AND (students OR classroom OR course)
Inquiry / experimentation	("generative AI" OR LLM OR ChatGPT) AND (inquiry OR "inquiry-based" OR experiment* OR "project-based") AND (science OR STEM)
Assessment and integrity	("generative AI" OR ChatGPT OR LLM) AND (assessment OR exam* OR "academic integrity" OR plagiarism OR cheating) AND (science OR STEM OR education)
Teacher professional development	("generative AI" OR ChatGPT OR LLM) AND (teacher* OR faculty) AND ("professional development" OR training OR pedagogy) AND (science OR STEM)
Indian context filter (optional)	("generative AI" OR ChatGPT OR LLM) AND ("science education" OR STEM) AND (India OR Indian OR CBSE OR DIKSHA OR NDEAR OR NEP)

Search string notes:

- Use truncation where supported (e.g., experiment*).
- In Scopus/WoS, consider field limits (TITLE-ABS-KEY or TS=).
- Add discipline terms (e.g., “chemistry education”).
- For multimodal GenAI, add “multimodal”, “image generation”, “prompting”, or “prompt literacy”.

C3. Screening Workflow and Data Extraction Fields

Workflow: export results → deduplicate → title/abstract screening → full-text screening → code and synthesize → report using PRISMA 2020 flow diagram and checklist (Page et al., 2021).

Extraction category	Example fields
Bibliographic	Author(s), year, country, venue
Context	School/HEI; grade level; discipline; region
Intervention	Tool type; prompts; duration; supervision
Design	Qual/quant/mixed; sample; comparison
Outcomes	Understanding; reasoning; writing; engagement; performance
Risks/ethics	Accuracy; bias; privacy; integrity; equity
Implementation	Training; policy; infrastructure; verification
Key findings	Results + limitations + recommendations

Ethics, Governance, and Academic Integrity (India-focused)

Responsible GenAI use in science education requires layered safeguards: classroom rules, institutional policies, and system-level governance. UNESCO's global guidance highlights data privacy protection, transparency, and human agency, noting that educational systems should validate GenAI tools for ethical and pedagogical suitability *(UNESCO, 2023)*. NDEAR's guiding principles (privacy and security by design; interoperability) provide an Indian digital-architecture lens for how GenAI could be deployed through controlled, auditable services rather than unmanaged public tools *(Ministry of Education, 2022)*.

Academic integrity is a central concern because GenAI can generate novel text that may bypass traditional similarity-based plagiarism detectors. Indian HEIs already operate within UGC academic integrity regulations; however, GenAI introduces new forms of 'unattributed assistance' that are not always captured by plagiarism definitions *(University Grants Commission, 2018)*. A practical response is to shift from purely product-focused assessment to process-focused evidence: requiring drafts, lab notebooks, data provenance, reflective decision logs, and oral defence. This approach both deters misuse and strengthens scientific reasoning as an assessed outcome.

Privacy and child safety are especially important in school settings. As a baseline, teachers should enforce a no-PII (personally identifiable information) rule in prompts, use anonymized student work for demonstrations, and prefer institutionally managed accounts where possible. Schools can align GenAI adoption with existing digital policies and use DIKSHA resources for verification so that learning does not depend on the accuracy of a single model output *(DIKSHA, 2026).*

Equity is a governance issue as well as a pedagogical one. If GenAI is used for homework or take-home projects without ensuring access and guidance, it may widen existing achievement gaps. Equity-first design includes guided in-class use, offline alternatives, and grading criteria that reward reasoning and evidence rather than polished language alone. Multilingual scaffolds should be validated to ensure that translation does not introduce scientific errors or cultural distortions.

Limitations of the Current Evidence Base

The evidence base on GenAI in science education remains emergent. Many studies are short-term, focus on perceptions rather than objective learning outcomes, and are concentrated in higher education contexts. Measurement approaches vary widely (writing quality, self-reported usefulness, engagement proxies), making cross-study comparison difficult. Additionally, rapid tool evolution (new model versions and features) can reduce the generalizability of findings across time. Consequently, this chapter emphasizes design principles and governance-aligned practices that are robust across tools, rather than tool-specific claims.

India-specific empirical studies on GenAI in school science are still limited. Contextual factors—language diversity, device availability, class size, and local curricular constraints—likely moderate GenAI's effects. Therefore, pilot implementations should include local evaluation and iteration, consistent with NEP 2020's emphasis on context-appropriate evaluation before scale-up *(Ministry of Education, 2020).*

Future Research Agenda for India

Future research in India should prioritize discipline-specific and longitudinal evaluation. Key questions include: (1) Does GenAI-supported instruction improve conceptual understanding and reduce misconceptions over time? (2) How does GenAI affect inquiry skills, including hypothesis quality, variable control, and interpretation of uncertainty? (3) What forms of assessment redesign best preserve integrity while promoting deep reasoning? (4) How do multilingual supports influence science learning across home languages, and what validation routines are required? (5) What governance models (privacy-preserving deployment, audit logs, institutional policies) work best within NDEAR-aligned digital ecosystems?

Methodologically, design-based research can be valuable because it iteratively refines GenAI-supported learning designs in real classrooms while collecting evidence on mechanisms and outcomes. Large-scale teacher professional development studies—potentially delivered via

DIKSHA—can examine how teacher AI literacy, prompt design competence, and classroom norms influence student outcomes and integrity incidents.

Conclusion

GenAI is poised to influence science education by changing how explanations are generated, how writing is supported, and how inquiry activities are scaffolded. The evidence synthesized here suggests that benefits are real but conditional: GenAI supports learning when embedded in pedagogical designs that require verification, preserve learner agency, and align assessment with reasoning. Risks—accuracy, integrity, privacy, and equity—are also real and must be addressed through layered safeguards. India's policy landscape *(NEP 2020, NCF-SE 2023),* digital infrastructure *(DIKSHA, NDEAR),* and national AI capacity-building (IndiaAI Mission) provide strong foundations for responsible adoption. The S-CIENTIFIC framework and classroom examples offered in this chapter provide practical pathways for Indian science educators to harness GenAI as a scaffold for scientific temper and inquiry—without reducing learning to AI-generated output.

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