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Current Trends in Science Education: A Systematic Review

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Abstract
The period from 2020 to 2026 has witnessed unprecedented transformation in science education, driven by the COVID-19 pandemic, rapid advances in educational technology, and international curriculum reform. It is critical for the educators and policy makers globally to understand which teaching strategies most effectively promote cognitive outcomes, science competency skills, and attitudinal outcomes in school-level learners. The present paper aimed to conduct the systematic review to examine the effectiveness of teaching strategies at school-level science education, focusing on three outcome domains: (1) cognitive outcomes (academic achievement, critical thinking, knowledge retention), (2) science competency skills (inquiry skills, problem-solving, 21st-century skills), and (3) attitudinal outcomes (motivation, interest, self-efficacy). A systematic search was conducted across four open databases—ERIC, Scopus, PubMed Central, and DOAJ—using pre-defined Boolean search strings. Studies published between January 2020 and June 2026 targeting school-level science education were eligible. 87 studies were selected that met the inclusion criteria (included meta-analyses, experimental, quasi-experimental, and qualitative studies). Results indicated - Inquiry-Based Learning (IBL) demonstrated the strongest cognitive benefits (Cohen's d = 0.62–0.81), while STEM-integrated approaches showed broad competency skill development (effect size = 0.57 for higher-order thinking). Project-Based Learning and Problem-Based Learning significantly improved science competency skills 21st-century skills. Technology-integrated strategies, particularly Augmented Reality (AR) and gamified environments, showed moderate to strong attitudinal benefits (d = 0.54–0.73) and meaningful cognitive gains. Student-centered pedagogies consistently outdid traditional instruction across all three outcome domains.

Key words: science education, systematic review, teaching strategies, cognitive outcomes, science competency skills, attitudinal outcomes.

1. Introduction

Science education at the school level prepares students for 21st-century skills, scientific literacy and attitude, and future workforce participation. The ability to understand and apply scientific principles, engage in rational thinking and logical reasoning, and develop positive temperaments toward science are widely recognized as essential competencies in contemporary knowledge economies (OECD, 2023; European Commission, 2015). Despite sustained investment in science education is there throughout the world including India, significant correspondence may not exist between research evidence and classroom practice.

The period from 2020 to 2026 has been significant for science education globally. The COVID-19 pandemic in a way forced the educators to think beyond traditional instructional delivery, encouraging them in the adoption of digital and hybrid learning environments (OECD, 2025). Apart from this, international assessments— PISA 2022 and TIMSS 2023—raised renewed concern about declining student achievement and engagement in science, particularly in secondary school contexts (Teig et al., 2022). This led to increased curiosity in identifying effective teaching strategies capable of improving cognitive outcomes, science competency skills, and attitudinal outcomes.

A large number of empirical researches have examined a wide range of pedagogical approaches: viz. inquiry-based and project-based approaches, STEM integration, technology-integrated learning, and gamification in multiple journals, databases. So, there is need to consolidate the current trends in science education in the light of teaching strategies and learning outcomes. This systematic review attempts to address the three interconnected research questions:

- What teaching strategies have been shown to improve cognitive outcomes—including academic achievement, critical thinking, and knowledge retention—in school-level science education between 2020 and 2026?
- What strategies most effectively develop science competency skills, including inquiry, problem-solving, and 21st-century skills?
- What is the evidence base regarding attitudinal outcomes—such as motivation, interest, and self-efficacy—associated with different pedagogical approaches?

Significance of the study

Most of the previous systematic reviews of science education have tended to focus on a single pedagogical approach (e.g., inquiry-based learning or technology integration) or a single outcome domain (e.g., achievement/retention test scores). This review attempts to examine multiple strategies and multiple outcome domains simultaneously, enabling multiple-strategy comparisons and offering a broader picture of what establishes effective teaching strategy in science. The review is restricted to open-access databases and school-level publications within January 2020 to June 2026. This ensures present-day relevance and availability of its evidence base as the post-2020 period captures the distinguishing pedagogical transformations shaped by the pandemic, digital revolution, and updated curriculum frameworks.

The student-centred aspect of education is grounded in constructivist theory, which suggests that learners actively construct knowledge through experience and social interaction (Vygotsky, 1978; Piaget, 1970). The cognitive-affective and skills framework (Bloom et al., 1956; adapted for 21st-century contexts) provides the structure—cognitive, competency skills, and attitudinal—that organizes the review's outcome analysis. In addition to these, the STEM competency framework articulated by Zhu et al. (2021), which includes scientific concepts, inquiry skills, engineering design, and computational thinking, forms the competency component of the analysis.

2. Methodology

The search was conducted across open-access databases and peer-reviewed publications from January 2020 to June 2026 in English: ERIC (Education Resources Information Center), Scopus (open-access subset), PubMed, and the Directory of Open Access Journals (DOAJ), International Journal of Science Education, Eurasia Journal of Mathematics, Science and Technology Education, and Frontiers in Education.

Search strings combined terms from three conceptual clusters: (1) teaching strategies (e.g., "inquiry-based learning," "project-based learning", "problem-based learning", "STEM," "augmented reality," "gamification," "scaffolding"), (2) science education context (e.g., "science education," "science learning," "science achievement", "science retention"), and (3) school-level populations (e.g., "elementary," "secondary," "K-12," "primary school," "high school").

Inclusion and Exclusion Criteria

Criterion	**Inclusion**	**Exclusion**
Publication type	Peer-reviewed empirical articles, systematic reviews, meta-analyses	Conference abstracts, book chapters, grey literature, editorials
Time period	January 2020 – June 2026	Published before 2020 or after June 2026
Educational level	School level: primary, middle, secondary (K–12)	Higher education, vocational training, teacher education only
Subject	Science, STEM, biology, chemistry, physics, earth science	Mathematics, technology, or engineering only (without science component)
Language	English	Non-English publications without English abstract
Access	Open access / freely available full text	Paywalled journals with no open access version
Outcome measures	At least one quantifiable outcome (cognitive, competency, or attitudinal)	Studies reporting only process data without measurable outcomes

354 studies passed the eligibility criteria after screening the title and abstracts, 277 were excluded due to insufficient data and grey literature. Finally, 77 studies were shortlisted includes 24 meta-analyses/systematic reviews, 31 experimental/quasi-experimental studies, 14 mixed-methods studies, and 8 qualitative studies.

It was found that there is heterogeneity in study designs, populations, and measurement instruments in the extracted data, so a narrative synthesis approach was employed as analytical method complemented with effect sizes from included meta-analyses and experimental studies. Effect size was interpreted by following Cohen (1988). Thematic analysis was applied to qualitative findings to identify convergent and divergent patterns across the literature.

3. Results

The final corpus comprised 77 studies published between January 2020 and June 2026, drawn from 18 countries across six continents. The majority of studies were conducted in Asia (38%), followed by

Europe (22%), North America (19%), and other regions (21%). Studies ranged in scope from single-classroom interventions (n < 50) to large-scale multi-country meta-analyses encompassing hundreds of thousands of participants. Secondary school level (Grades 7–12) was the most frequently studied context (52%), followed by elementary/primary school (36%), and mixed K–12 samples (12%). The six most studied teaching strategies were: Inquiry-Based Learning (IBL), STEM/integrated STEM education, Project-Based Learning (PjBL), Problem-Based Learning (PBL), technology-enhanced learning (including AR/VR/gamification), and scaffolding/formative assessment.

Table 1

Evidence Summary: Teaching Strategies, Outcome Domains, and Effect Sizes (2020–2026)

Teaching Strategy	Outcome Domain	Effect Size (d / g)	Key Evidence	Quality of Evidence
Inquiry-Based Learning (IBL)	Cognitive (critical thinking)	d = 0.62–0.81	Arifin et al. (2025); Gomez (2025); IBL meta-analysis 21 studies	Moderate–High
Inquiry-Based Learning (IBL)	Attitudinal (interest/motivation)	d = 0.58	PISA 2015 analysis; TIMSS-linked studies	Moderate
Project-Based Learning (PjBL)	Cognitive (achievement + creative thinking)	Normalized gain = 0.47 (exp) vs 0.25 (control group)	Sari et al. (2025); meta-analysis elementary science	Moderate–High
Project-Based Learning (PjBL)	Competency (21st-century skills)	d = 0.55–0.78	Computational thinking meta-analysis (Zhang et al., 2024)	High
Problem-Based Learning (PBL)	Cognitive (critical thinking)	d = 0.63	Hafizah et al. (2024); blended PBL studies	Moderate
STEM/Integrated STEM	Cognitive (academic performance)	d = 0.42	Cao et al. (2025); 66-study meta-analysis	High
STEM/Integrated STEM	Competency (higher-order thinking)	d = 0.57	STEM umbrella review (22 meta-analyses, 226,845 students)	High
Technology-Enhanced (AR/VR)	Cognitive (knowledge acquisition)	g = 0.73 (AR); d = 0.65 (VR)	Kalemkus & Kalemkus (2023); Villena-Taranilla et al. (2022)	Moderate

Technology-Enhanced (AR/VR)	Attitudinal (motivation/attitude)	d = 0.54	AR meta-analysis 2016–2023; ARCS model studies	Moderate
Gamification / Digital Games	Attitudinal (motivation, STEM interest)	d = 0.52	Arztmann et al. (2022); OECD 2025	Moderate
Scaffolding / Formative Assessment	Cognitive (learning outcomes)	d = 0.48–0.72	EEF Toolkit (2025); Azzaroiha et al. (2025)	Moderate–High
Hands-on / Laboratory	Competency (problem-solving, inquiry)	d = 0.61	Innovative teaching review (Acta Paed., 2025)	Moderate
Student-Centered Approaches	Cognitive + Attitudinal	d = 0.54	PRISMA review 18 studies 2020–2025	Moderate

Cognitive Outcomes in Science Education

Cognitive outcomes encompass academic achievement (test scores, grades), knowledge retention, conceptual understanding, and higher-order thinking skills (critical thinking, problem-solving, metacognition). These outcomes were the most frequently measured across the included literature, appearing in 91% of studies.

Table 2

Summary of effectiveness of teaching strategies with respect to cognitive outcomes

Teaching Strategy	**Cognitive Outcomes**	**Typical Effect Size**	**Grade Level Strength**	**Key Moderators**
Inquiry-Based Learning (IBL)	Critical thinking, conceptual understanding, HOTS	High	Secondary > Primary	Teacher facilitation, structure level
Project-Based Learning (PBL)	Academic achievement, knowledge retention	Moderate to large	Middle & Secondary	Driving question quality, collaboration
Scaffolded Instruction	Concept understanding, argumentation, HOTS	Moderate to Large	All levels	Scaffold fading, digital support
Flipped Classroom	Academic achievement (content-heavy subjects)	Moderate	Secondary	Pre-class compliance, content type

STEM Integration	Cognitive outcomes, problem-solving	Moderate	High school strongest	Implementation period, subjects, level

Inquiry-Based Learning (IBL) and Cognitive Development

Inquiry-Based Learning emerged as the most extensively studied strategy in relation to cognitive outcomes, appearing in 24 of the 77 included studies. A systematic review and meta-analysis (Arifin et al., 2025) examined 42 experimental studies on IBL's effect on students' critical thinking skills in science, reporting a large weighted mean effect size of d = 0.81. The analysis found that IBL was particularly effective at the secondary school level and in biology and chemistry contexts, with structured inquiry (guided questioning with clear scaffolding) outperforming open inquiry for students with lower prior knowledge.

Gomez (2025) in his review establishes that IBL improved academic achievement when technology was integrated rather than used as standalone. It was also found that how teacher creates a productive classroom environment and provide timely instructional scaffolding—was a deciding factor/moderating variable for IBL effectiveness. Gomez and Suárez (2020) also reported that inquiry-based teaching significantly enhanced science achievement and critical thinking across 57 countries, with school environment playing a significant mediating role. A systematic review studies of TIMSS and PISA - two major international assessments used to evaluate education system, noted that these instructional features of higher cognitive and affective outcomes are particularly valuable for fostering scientific literacy and preparing students for informed citizenship (Teig et al., 2022).

Project-Based Learning and Problem-Based Learning

Project-Based Learning was also found to cause strong effects on cognitive outcomes at both elementary and secondary levels. A meta-analysis conducted to see its effect on critical thinking ability in science of elementary students (Sari, Festiyed, & Yerimadesi, 2025), reported the superiority of PBL as the effect size was found to be significantly moderate. Another meta-analysis of 31 experimental and quasi-experimental studies found that project-based learning elevates the computational thinking assessed across: "innovation, collaboration, critical analysis, algorithmic cognition, and problem resolution," with effect sizes ranging from d = 0.55 to d = 0.78 depending on grade level and subject area (Zhang et al., 2024). For knowledge retention, several studies reported that gains continued at 4 to 8-week follow-up on assessments, suggesting deeper learning of concepts.

One of the important factor/moderators identified across multiple studies was the quality of the driving question: the central question that was directly connected to students' life or concrete experiences reported approximately 30% higher effect sizes on achievement than those with abstract or unrelated to daily life questions. Collaborative PBL formats (small groups of 3–5 students) too outperformed individual project work on most cognitive outcome measures. Problem-Based Learning (PBL), particularly when implemented in blended or technology-assisted formats, showed comparable benefits for critical thinking development in science as shown by meta-analysis (Lu et al, 2025). The review highlighted that PBL's effectiveness is enhanced by structured support mechanisms: clear problem framing, formative feedback, and collaborative group structures. Studies by Fitriani et al. (2020) and

Santyasa et al. (2019), included in this corpus, demonstrated PBL's significant effectiveness in biology and physics respectively,

STEM Integration

The STEM based meta-analysis conducted across 66 experimental and quasi-experimental studies found a mean effect size of 0.42 for academic performance and knowledge retention (Cao, et al. 2025). Moderator analysis revealed that when STEM is integrated with problem-solving method producing the strongest cognitive effects.

Another review synthesizing 22 meta-analyses across 23 countries found that STEM education's overall effect on learning achievement was below 0.7 but practically significant: the effect on learning achievement was 0.42, on higher-order thinking skills 0.57, and on cognitive outcomes broadly 0.59 (Lu, et al. 2025). These figures underscore that STEM's cognitive benefits are real but context-dependent, and that the quality of integration—rather than the mere tag of "STEM"—is the deciding factor.

Scaffolding Instruction

A systematic literature review on scaffolding strategies in science (Sari et al., 2024), found that scaffolding positively impacts students' cognitive and affective learning outcomes, concept understanding, science process skills, argumentation skills, critical thinking, higher-order thinking skills (HOTS), and learning independence. The most widely used scaffolding model was Problem-Based Learning (PBL) integrated with structured scaffolding supports.

Flipped Classroom

Results for flipped classroom model in science education were moderately positive for academic achievement (mean effect d = 0.48) but more heterogeneous than for IBL or PBL. The flipped model looked most effective in physics and chemistry courses at the secondary level, where subject matter is very heavy and pre-loaded instructional videos are quite beneficial before actual problem solving in the class and laboratory work. Students actually watching videos before class was a critical moderator of its effectiveness, when there is lower compliance then this results in negligible or even negative effects.

Technology-Enhanced Strategies

Augmented Reality (AR) emerged as one of the most actively researched technology-enhanced strategies in the 2020–2026 period. Kalemkuş and Kalemkuş (2023), in a meta-analysis of AR applications in science education, reported a medium-to-large effect size (g = 0.73) on students' academic achievement in science. A comprehensive systematic review and meta-analysis of AR in higher and school education (Li et al, 2025), covering 237 articles and 60 experimental studies from 2000 to 2023, found that AR was particularly effective for knowledge acquisition and conceptual understanding, especially in biology, chemistry, and Earth science.

For Virtual Reality (VR), a meta-analysis of K–6 education (Villena-Taranilla et al., 2022) reported positive effects on learning outcomes (d = 0.65), with the strongest effects for science content that benefits from three-dimensional spatial visualization. Learning gains were substantially greater when AR/VR were integrated within structured pedagogical frameworks rather than used as standalone tools.

4. Science Competency Skills

Out of number of skills, the science competency skills: inquiry skills, problem solving and 4 Cs of 21st century skills formed the part of study. These skills have assumed increasing prominence in the school curricula and were assessed in 68% of included studies.

Table 3

Summary of strategies for science competency development skills

Competency Domain	Top Strategies	Evidence Strength	Key Findings
Inquiry Skills	IBL, IBSE, technology-enhanced inquiry	Strong (multiple meta-analyses)	Teacher facilitation & explicit scaffolding are critical
Problem-Solving	PBL (5-phase), scaffolded problem-solving	Strong	Synergistic effect when PBL + scaffolding combined
Critical Thinking	IBL, SSI, blended + inquiry	Strong (g = 0.73 to 1.06)	Collaborative formats outperform individual
Creativity	PBL, maker education, design thinking	Moderate–Strong	Project-based maker activities most effective
Communication & Collaboration	SSI, cooperative learning, PBL groups	Moderate	SSI strongest for argumentation development
Digital Literacy	Technology-enhanced IBL, AR, simulations	Moderate	Technology as catalyst, not substitute, for inquiry

Inquiry and Problem-Solving Skills

The development of inquiry competencies—hypothesis generation, experimental design, data analysis, and evidence-based argumentation—was the most frequently targeted competency outcome across the included literature. IBL studies consistently documented significant improvements in students' ability to design and conduct investigations, interpret data, and communicate scientific findings. A systematic review of STEM competencies (Zhu et al., 2021) identified five core dimensions of STEM competency: scientific concepts, scientific thinking, inquiry practices, engineering design, and systems thinking, providing a validated framework for competency assessment that was adopted by 14 of the 77 included studies.

Hands-on and laboratory-based learning retained strong empirical support for competency development in the current period. The systematic review by Rahe et al. (2025) found that hands-on learning "enhanced engagement and problem-solving skills" across all grade levels, though it also identified persistent resource constraints as a significant implementation barrier, particularly in under-resourced school systems.

STEM-Integrated Competency Development

The integrated STEM approach proved to be the strongest in the development of competency skills. The meta-analysis by Cao et al. (2025) found that STEM education produced a mean effect of 0.57 on higher-order thinking, creativity, and collaborative problem-solving as compared to 0.42 for convention cognitive variable academic performance. This suggests that STEM approach is more effective for competencies than academic achievement. A systematic literature review on secondary STEM learning outcomes (Portelo-Blanco, et al. 2023), found that STEM approaches consistently improved motivation, higher-order thinking skills, and learning achievement, with 76% of included studies published after 2017 reflecting the rapid growth.

Particular attention has been paid to computational thinking (CT) as an emerging STEM competency. A systematic review by Alibek and Akhmetova (2025) examined CT skill development in STEM for kindergarten children, drawing on systematic reviews by Alexandre et al. (2022) and Aguilera & Ortiz-Revilla (2021), and found that STEM and STEAM interventions yielded positive results on creative thinking, though assumptions that STEAM is unambiguously superior to STEM for creativity were not consistently supported by empirical evidence.

21st-Century Skills

A meta-analysis on blended learning integrated with inquiry-based learning (Sujarwo et al., 2025) reported that the application of blended and inquiry-based learning models significantly improved students' 21st-century thinking skills compared to conventional models ($g = 1.062$; 95% CI: 0.45–0.93; $p < 0.001$). Moderator analysis showed that variation in implementation model, education level, and subject area enhanced effect magnitudes with secondary level science subjects showing the strongest effects.

Project-Based Learning as a strategy turned out be enhancing 21st-century skills—specifically collaboration, communication, and creative thinking alongside academic achievement as affirmed by a meta-analysis (Zhang, et al. 2024). Tafakur et al. (2023) in a meta-analysis too reported that project-based learning produced significantly higher critical thinking when assessment was embedded within the project rather than administered as a separate post-test.

5. Attitudinal Outcomes in Science Education

Attitudinal outcomes encompass students' motivation to learn science, interest in science, self-efficacy beliefs, and attitudes toward STEM careers. These outcomes are recognized as critical precursors to long-term science engagement and were measured in 61% of included studies, reflecting their growing prominence in the post-pandemic literature.

Table 4

Attitudinal outcomes by pedagogical approach

Attitudinal Construct	**Most Effective Strategies**	**Effect Magnitude**	**Key Mechanisms**
Intrinsic Motivation	Autonomy-supportive pedagogy, SDT-based	Large	Satisfying autonomy, competence, relatedness needs

	instruction, gamification		
Individual Interest	Sustained IBL, field science	Moderate (with sustained exposure)	Transition from situational to individual interest
Science Self-Efficacy	Scaffolded IBL, SRL+AR gamification, formative PBL	Large (mediating role)	Mastery experiences, self-monitoring, progressive challenges
Attitude toward Science	Hands-on labs, STEM projects, AR-based learning	Moderate	Active engagement, visualization of abstract concepts

Motivation and Attitude

Digital and technology-enhanced strategies demonstrated the most robust and consistent effects on attitudinal outcomes in the included literature. A meta-analysis on AI technologies in education (Su et al., 2022) documented that AI-based learning tools effectively strengthened students' attitudes toward learning. For digital game-based learning, Arztmann et al. (2022) reported positive effects of digital games on motivation and behavior toward STEM subjects, with no significant gender differences in motivational impact—an important equity-relevant finding.

Augmented Reality demonstrated consistently positive attitudinal effects. A meta-analysis examining AR's impact on student attitudes, motivation, and learning achievements, found that learners' attitudes toward AR-assisted education were significantly more positive compared to those without AR, and that learning achievements were significantly higher in AR-supported conditions (Cao, et al. 2025). Technology-enhanced science learning at the elementary level, examined in a cross-cultural study using sequential mixed-methods design (Barak et al., 2023), found that phases of technology integration that gave students help over digital tools (using sensors and data recorders) were most strongly associated with positive motivation, particularly for cross-cultural samples.

Student-Centered Approaches and Attitudinal Outcomes

Student-centered pedagogies—broadly defined to include collaborative learning, differentiated instruction, and learner-directed inquiry—showed positive but more variable attitudinal effects than technology-specific strategies. The review of innovative teaching strategies (Rahe et al., 2025) found that student-centered approaches "promoted critical thinking and collaboration but demanded alternative assessment methods," and that attitudinal benefits were contingent on adequate implementation support, including teacher training in facilitating open-ended learning. Studies from East Asian school contexts, in particular, documented tension between student-centered approaches and high-stakes examination culture, with motivational benefits sometimes undermined by assessment pressure.

Self-efficacy

A study (Basileo et al. 2024) found that self-efficacy has a large effect on students' use of deeper learning strategies and their ability to transfer learning to novel contexts. Pedagogical approaches that provide frequent mastery experiences—such as guided inquiry with scaffolding, formative assessments embedded in Problem based learning, and gamified learning with progressive challenges—were associated with the strongest self-efficacy gains.

Interest

Interest in science was determined in the form of pursuing careers in STEM—long-term attitudinal outcomes extending beyond classroom motivation—were examined in 18 of the 77 included studies, predominantly at the secondary school level. The K–12 STEM systematic review found that integrated STEM approaches consistently improved students' interest in STEM careers, though the evidence for sustained effects beyond the immediate intervention was limited (Portelo-Blanco, et al. 2024). Stringer et al. (2020) and Allen et al. (2019), found that STEM extracurricular programs positively influenced motivation towards STEM.

6. Discussion

Inquiry-based approach turned out to be the most across all three outcome domains. The effect sizes ranging from d = 0.62 to d = 0.81 provides strong justification for effective curriculum transaction prioritizing higher order cognitive skills at all school levels. The moderator analyses converge on key points: the quality of its implementation—how effectively teacher conduct scaffolding inquiry and other steps of the strategy and create a conducive learning environment. This finding suggests the importance of sustained teacher professional development.

The other approaches IBL, PBL or STEM integration too emphasize the student-centred pedagogical principle -- students as active constructors of knowledge—rather than passive recipients of information— this principle emerges as the central force or reason behind all positive outcomes, also aligns with established constructivist theory (Vygotsky, 1978; Piaget, 1970) and extends it into the contemporary digital classroom.

The evidence on technology-enhanced learning reveals that digital technologies—including AR, VR, AI-based tools, and gamified environments—consistently demonstrate positive effects on both cognitive and attitudinal outcomes, but their effectiveness is mediated by pedagogical integration quality. The OECD (2025) working paper reinforces this finding, noting that "tools alone do not transform education" and that the impact of digital tools on learning and motivation "relies heavily on teachers' practices, choices," and curricular alignment. This indicates that technology is an amplifier or just an assistant not a replacement.

The moderate-to-large effect sizes associated with AR use in science education (g = 0.73 for academic achievement) are significant, suggests making mobile AR technology available to all students irrespective to their background and its cost-effectiveness relative to VR. The review identified equity concerns: AR and VR experiences remain inaccessible in under-resourced schools in remote areas or to under-privileged society in developing countries. This also raise important questions whether technology-centred strategies widening achievement gaps unintentionally rather than reducing them. So, technology integration has to address questions of equitable access.

Regarding attitudinal component, this seems unintentionally neglected as in most of the studies major emphasis is given on cognitive and competency outcomes. Though attitudinal outcomes are the part of study but many researchers prepared intervention programme that are acquiescent with cognitive and competency outcomes. So, attitudinal outcomes received less attention as far as strategical procedure is concerned. In literature, fewer studies are employing validated instruments and longitudinal follow-up. Yet the evidence that is available is noteworthy: students' attitudes toward science are strong predictor of students taking science as careers and have long-term association with science. These attitudes are shaped by meaningful classroom experiences. The finding that technology-enhanced and gamified environments produce positive attitudinal effects, sometimes even when cognitive gains are modest, suggests that these strategies may play a distinctive role in building the affective foundations for science as a disciplinary subject. The cross-cultural findings from technology-enhanced science learning (Barak et al., 2023) are encouraging in suggesting that well-designed experiences can foster positive motivation across diverse cultural contexts. For all student-centred strategies to be effective, the main moderating variable is the tension between student-centred approaches and high-stake examination culture that is highly marks oriented. Due to this, attitudinal benefits may be undermined if the broader assessment ecology rewards passive knowledge reproduction over active inquiry.

7. Limitations of this Review

- The search is restricted to English-language publications may have excluded important research from non-English-speaking countries.
- The restriction to open-access databases, while consistent with the review's accessibility goals, means that high-quality studies published in subscription-only journals were not captured.
- The heterogeneity of included studies—spanning different strategies, contexts, grade levels, and outcome measures—limits the precision of cross-strategy comparisons.

8. Conclusions and Implications

This systematic review provides a comprehensive and current synthesis of evidence on effective teaching strategies in school-level science education, organized around three outcome domains: cognitive outcomes, science competency skills, and attitudinal outcomes. The following conclusions are drawn from the evidence base:

- Inquiry-Based Learning (IBL) is the most robustly supported strategy for cognitive outcomes, particularly critical thinking, with effect sizes consistently in the medium-to-large range (d = 0.62–0.81). Its effectiveness is maximized when combined with controlled scaffolding and continuous teacher support.
- STEM-integrated education establishes the most comprehensive competency benefits, with positive effects on higher-order thinking (d = 0.57), academic performance (d = 0.42), and science interest, though the way of its integration is the deciding moderating factor.
- Project-Based Learning and Problem-Based Learning show strong effects on critical thinking and 21st-century skills (d = 0.55–0.78), particularly at the secondary level, and are most effective when real life questions are presented as stimulus to start the learning cycle; collaboration, and formative assessment are also embedded throughout the learning cycle.
- Technology-enhanced strategies—particularly Augmented Reality, gamification, and AI-assisted tools—produce positive attitudinal effects (d = 0.54–0.73) and meaningful cognitive gains, but require pedagogically sound integration and equitable access be taken care of in terms of internet and devices to realize their potential.

- Attitudinal outcomes are shaped by the entire ecology of science learning, including classroom climate, cultural context, and the diverse assessment environment, and deserve greater methodological attention in future.
- Implementation challenges—resource constraints, teacher readiness and competency skills, and equity of access—are universal barriers that are manageable for evidence-based strategies to benefit all students.

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