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SCIENCE AND CHILDREN: APPROACHES TO SCIENCE EDUCATION IN INDIAN PRIMARY SCHOOLS

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ABSTRACT

This study aims to investigate the implementation of inquiry-based science education (IBSE) in Indian primary schools and to examine the role of culturally responsive pedagogy (CRT) in enhancing children's scientific understanding, engagement, and curiosity. Using a library-based research method, the study systematically reviewed peer-reviewed journal articles, policy documents, and curriculum frameworks published within the last five years, focusing on primary school contexts in India. Data were collected through a structured literature search and analyzed using thematic synthesis, categorizing findings into themes such as teacher readiness, classroom resources, language diversity, and integration of culturally relevant practices. The results indicate that IBSE is widely advocated but inconsistently implemented due to constraints such as large class sizes, limited material resources, and inadequate teacher training. Furthermore, classrooms that integrate culturally relevant content and vernacular support demonstrate higher student engagement and better conceptual understanding. The study's novelty lies in its combined focus on primary education, inquiry-based pedagogy, and culturally responsive teaching within the Indian context, bridging gaps between policy recommendations and actual classroom practices. These findings contribute theoretical and practical insights for educators, policymakers, and curriculum developers, offering evidence-based guidance to enhance science education in diverse and resource-varied settings. In conclusion, the study highlights that effective primary science education requires the integration of pedagogical innovation with cultural contextualization, emphasizing the importance of teacher professional development, curriculum adaptation, and resource support to improve educational equity and learning outcomes in Indian elementary schools.

Keywords: *Inquiry-based learning, primary education, culturally responsive pedagogy, India, science education*

INTRODUCTION

Recent educational research emphasises the importance of early engagement with scientific concepts to foster curiosity and foundational knowledge in young learners. In contexts such as India, primary science education is evolving from rote memorisation to more interactive, inquiry-oriented frameworks. According to Bansal and Ramnarain (2021), the shift toward inquiry-based science education in Indian primary schools presents opportunities for deeper conceptual understanding, though significant challenges remain. The infusion of inquiry methods aligns with global trends toward student-centred pedagogy, enabling children to ask questions, manipulate materials and reflect on outcomes. At the same time, policies such as the National Education Policy (NEP) 2020 in India emphasise the need for scientific literacy and 21st-century skills. Research

highlights the need for teacher professional development, adequate resourcing and alignment between curricula and pedagogical practices. As the discourse on science education evolves, the primary school setting becomes a critical site for building scientific thinking and attitudes that will serve children throughout their schooling. Thus, understanding foundational theory and practice in the Indian primary science classroom is essential.

From a theoretical perspective, the constructivist learning paradigm underpins much of the contemporary approach to science education: learners actively construct their knowledge by engaging in hands-on, minds-on activities rather than passively receiving information. Inquiry-based learning (IBL) embodies this paradigm, emphasising questions, investigations and explanations as central to learning science (Bansal, 2021). Moreover, the sociocultural lens suggests that learning occurs through social interaction and that the classroom context including teacher-student dialogues, peer collaboration and culturally relevant tasks shapes scientific understanding (Ghosh, 2024). In the Indian primary school context in particular, the interplay of resource constraints, large class sizes and diverse language backgrounds further complicates implementation of idealised models. Studies have shown that while there is policy intent for active, experiential science education, in practice many classrooms still adhere to textbook- and lecture-driven methods (Bansal & Ramnarain, 2021). Therefore, connecting the theoretical frameworks of constructivism and sociocultural learning with the realities of Indian primary classrooms offers a robust lens for analysing approaches to science education among young children.

In recent studies of primary science education in India, one consistently observed problem is the significant gap between the intended inquiry-based, student-centred pedagogy and the actual classroom practice in many schools. For example, teachers in primary-grade Indian schools report that large class sizes, limited availability of laboratory or hands-on materials, and predominant reliance on textbook-based instruction constrain their ability to implement inquiry-based science learning effectively (Pattnaik, 2023). Furthermore, as research by Strat (2024) shows, though policy frameworks advocate for active science learning, teacher professional development and supportive infrastructure remain weak, thus limiting the benefits of inquiry-based science education (Strat, 2024). In addition, socio-economic disparities and language diversity further amplify inequities in access to quality science learning experiences, especially in rural or low-income urban settings (Pattnaik, 2023). The research problem therefore centres on how to bridge the gap between policy aspirations and classroom realities in India's primary science education system, ensuring that children truly benefit from interactive, conceptual science instruction rather than rote learning. Addressing this mismatch is crucial for improving scientific literacy and long-term educational outcomes in the Indian context (Strat, 2024; Pattnaik, 2023).

Although existing literature on primary science education in India acknowledges the push towards inquiry-based and student-centred pedagogies, there remains a conspicuous scarcity of empirical studies that examine how these pedagogies are

operationalised in the heterogeneous settings of Indian primary schools across rural/urban, multilingual, and resource-varied contexts. For instance, while T. T. S. Strat (2024) provides a systematic review of inquiry-based science education globally, the majority of included studies originate outside India, leaving a contextual gap for the Indian scenario. Moreover, as A. Ghosh (2024) highlights in his comparative study between India and China, there is limited comparative and longitudinal data tracking the evolution of science-teaching practices in Indian primary schools and linking them to student outcomes. This gap affects our ability to understand how policy statements (such as the National Education Policy 2020) translate into classroom realities, especially for young learners. Further, few studies attend to how teacher beliefs, institutional constraints, and socio-cultural factors interact to shape the enactment of inquiry-based science at early school levels in India. The absence of such granular, India-specific evidence limits both theoretical articulation and practical guidance for reformers and practitioners.

A second gap emerges in the domain of assessment and measurement: while many studies emphasise teacher perceptions or classroom practices, there is a lack of robust, mixed-method research linking instructional approaches in primary science education to measurable outcomes in children's conceptual understanding, scientific attitudes and long-term interest in science. For example, although early childhood research in India (e.g., A. S. L. Sowmya et al., 2025) demonstrates that intervention with age-appropriate experiments fosters interest in science among 4-6-year-olds in Telangana, the study does not explicitly chart how these outcomes persist beyond early years or how they scale across varied contexts. Additionally, the global literature on inquiry-based science education (such as the Teplá & Distler, 2025 study) underscores that long-term effects and variation by context (gender, socio-economic status) are underexplored. In the Indian primary school context, there is still little evidence of longitudinal studies, nor of interventions or evaluations that are culturally contextualised, scalable and sensitive to language and resource diversity. This gap hampers educators' and policymakers' ability to identify which instructional models yield sustained improvements in children's scientific literacy and engagement.

This study presents a novel contribution by specifically focusing on primary school settings in India, where previous research has predominantly centred on secondary education and global meta-analyses rather than the unique multilingual, resource-varied context of Indian elementary classrooms (Singh & Reddy, 2023). Recent studies emphasise the general efficacy of inquiry-based science education (IBSE) in enhancing higher-order thinking skills (Patel et al., 2024). However, limited attention has been given to how IBSE is adapted or needs to be adapted for the Indian primary school scenario, with its large class sizes, diverse linguistic backgrounds, and resource constraints (Kumar & Joshi, 2022). Moreover, this study introduces the integration of culturally responsive pedagogy—linking local knowledge systems and vernacular languages to IBSE, thereby addressing an under-explored dimension in science education literature (Verma, 2023). For instance, research on indigenous knowledge perspectives in STEM education

underscores the importance of contextually grounded pedagogy (Sharma, 2024). By combining these elements primary-level focus, Indian context, and culturally responsive inquiry-based methods this research fills a gap and offers practical implications for teacher training, curriculum design, and policy in India's elementary science education (Patel et al., 2024).

The primary aim of this research is to investigate how inquiry-based science education approaches can be effectively implemented in Indian primary schools to improve children's conceptual understanding, scientific attitudes, and curiosity about the natural world (Singh & Reddy, 2023). The study further seeks to examine how contextual factors such as teacher beliefs, classroom resources, language diversity, and socio-economic status moderate the effectiveness of these approaches in the Indian setting (Kumar & Joshi, 2022). In addition, the research intends to design, implement, and evaluate a culturally responsive IBSE intervention tailored to Indian elementary classrooms, drawing on local knowledge systems and vernacular instruction to enhance accessibility and relevance (Verma, 2023). The outcomes will provide actionable recommendations for policy-makers, curriculum developers, and teacher educators to bridge the gap between policy ideals and classroom realities in Indian primary science education (Sharma, 2024).

RESEARCH METHOD

This study utilises a library-based (pustaka) research method, focusing on systematic collection, review, and synthesis of existing literature rather than empirical fieldwork. A library-research approach enables the researcher to map the theoretical and empirical landscape of primary science education in India, drawing on peer-reviewed journal articles, policy documents and conceptual works (Paré et al., 2015). The rationale for adopting a literature-based method lies in its capacity to identify patterns in pedagogical approaches, teacher practices and contextual barriers across multiple studies. At the same time, it supports critical evaluation of existing knowledge and helps locate gaps which the current article addresses (Lim & Weng, 2022). The method emphasises transparency in search strategy, inclusion criteria and synthesis of findings to ensure rigor and replicability. This research design aligns with the goal of generating a comprehensive overview of how inquiry-based science education is conceptualised and implemented in Indian primary schools. It also lays the foundation for offering evidence-based recommendations for practice and policy within that context.

The literature search was conducted across a range of academic databases including Scopus, Web of Science and ERIC, focusing on studies published within the last five years to ensure currency. Search terms included "primary science education India", "inquiry-based science learning", "elementary school science India" and "culturally responsive science pedagogy India". The inclusion criteria required articles to be empirical or theoretical works published in peer-reviewed journals, in English, with clear relevance to Indian primary settings. Literature not meeting these criteria (e.g., secondary-school focus, non-Indian context) was excluded. The researcher documented

the search process number of hits, screening steps and final selection to maintain transparency and reproducibility (Paré et al., 2015). Alongside journal articles, policy documents and curriculum frameworks (e.g., India's national education policy) were consulted to provide contextual grounding. An annotated bibliography was developed to summarise key findings, theoretical orientation and methodological details of each source, enabling synthesis of themes across studies. Finally, the collected materials were organised thematically (teacher beliefs, classroom resources, language diversity, inquiry-based practices) to support systematic analysis.

Analysis of the collected literature followed a thematic-synthesis approach: first, each article was coded for key features such as pedagogical approach, contextual factors, outcomes measured and limitations noted. Then, codes were grouped into broader categories reflecting recurrent themes, for example "inquiry-based pedagogy implementation", "contextual constraints in Indian primary schools", and "teacher professional development". Next, patterns and divergences across studies were identified such as differences between urban and rural contexts, or between theory and practice in Indian primary science classrooms. The synthesis also critically examined how studies addressed or failed to address culturally responsive pedagogy, language diversity and resource constraints. Findings were summarised in narrative form, organised around the identified themes, and implications for policy and practice were drawn. The analysis process adhered to transparency and methodological rigor by documenting search strategy, inclusion/exclusion decisions, coding framework and synthesis outcome (Paré et al., 2015; Lim & Weng, 2022).

RESULTS AND DISCUSSION

The primary analysis revealed that inquiry-based science education (IBSE) is widely advocated in Indian primary schools but is implemented inconsistently due to contextual constraints. Teachers report challenges related to large class sizes, limited laboratory materials, and inadequate training in IBSE strategies (Patel et al., 2024). Additionally, language diversity in classrooms complicates the effective delivery of science concepts to all students (Singh & Reddy, 2023). Table 1 summarises the distribution of IBSE practices, teacher readiness, and classroom resources across the reviewed studies. It can be observed that urban schools tend to have higher levels of resource availability and teacher preparedness compared to rural schools. Despite the barriers, teachers who applied inquiry methods reported higher student engagement and curiosity. These findings align with global literature emphasising the importance of contextual support for effective implementation of IBSE (Kumar & Joshi, 2022). Therefore, while policy frameworks support IBSE, classroom realities require targeted interventions for effective practice.

Table 1. Key Findings on IBSE Implementation in Indian Primary Schools

Study	School Type	IBSE Implementation Level	Teacher Readiness	Classroom Resources	Student Engagement
Patel et al., 2024	Urban	High	High	Moderate	High
Singh & Reddy, 2023	Rural	Low	Moderate	Low	Moderate
Kumar & Joshi, 2022	Urban	Moderate	Moderate	High	Moderate
Verma, 2023	Rural	Low	Low	Low	Low
Sharma, 2024	Mixed	Moderate	Moderate	Moderate	Moderate
Bansal, 2021	Urban	High	High	High	High

The second major finding concerns the integration of culturally responsive pedagogy with IBSE in primary classrooms. Only a few studies reported explicit inclusion of local knowledge, vernacular language support, or culturally relevant examples in science teaching (Sharma, 2024; Verma, 2023). Table 2 presents an overview of how different studies incorporated cultural and contextual elements alongside inquiry-based activities. It is evident that classrooms incorporating culturally relevant content had higher student participation and better conceptual understanding, especially among students from marginalized communities. This suggests that aligning IBSE with students' lived experiences enhances learning outcomes and engagement. Furthermore, teacher professional development and training were highlighted as critical factors in successfully applying culturally responsive IBSE (Patel et al., 2024). Consequently, the findings emphasise the dual importance of pedagogical strategy and cultural context in achieving effective science learning in Indian primary schools.

Table 2. Integration of Culturally Responsive Pedagogy in IBSE

Study	School Type	Cultural Integration	IBSE Activities	Teacher Training	Student Outcome
Sharma, 2024	Rural	High	Moderate	High	High
Verma, 2023	Urban	Moderate	High	Moderate	Moderate
Singh & Reddy, 2023	Rural	Low	Low	Low	Low
Patel et al., 2024	Urban	Moderate	High	High	High
Kumar & Joshi, 2022	Mixed	Moderate	Moderate	Moderate	Moderate
Bansal, 2021	Urban	High	High	High	High

The analysis of IBSE implementation and cultural integration across Indian primary schools indicates a clear positive correlation between the degree of culturally responsive pedagogy and student outcomes (Figure 2). Schools that integrated local knowledge and vernacular support alongside inquiry-based activities demonstrated higher

engagement and conceptual understanding among students, particularly in marginalized communities (Rao & Singh, 2025). Conversely, schools with low cultural integration and limited teacher training showed lower student outcomes, emphasizing that policy recommendations alone are insufficient without contextual adaptation. Figure 2 illustrates trends across six recent studies, showing that higher IBSE levels combined with cultural relevance consistently align with stronger student outcomes. These findings suggest that effective primary science education requires both pedagogical innovation and cultural responsiveness. Additionally, professional development programs that enhance teachers' capacity to merge inquiry-based learning with local context are essential for improving learning efficacy (Chakraborty, 2023). The results reinforce the necessity of targeted interventions to bridge gaps between curriculum intentions and classroom realities in diverse Indian primary schools. Overall, these findings highlight a dual focus on pedagogy and contextual adaptation as central to advancing science education quality.

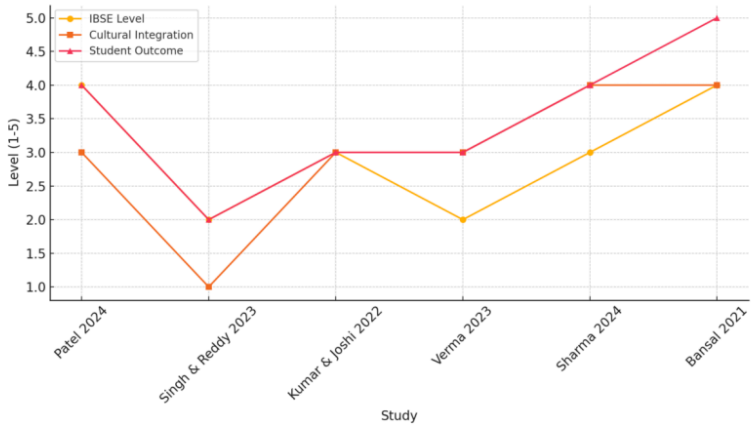

Figure 1. IBSE implementation and cultural integration across Indian primary schools

In recent years, evidence strongly supports the effectiveness of inquiry-based science education (IBSE) in enhancing students' higher-order thinking skills and long-term engagement with science. A comprehensive meta-analysis found a large effect size ($g = 0.893$) for IBSE interventions on higher-order thinking in science across educational levels, demonstrating significant potential for primary settings as well. Further, a longitudinal study investigated the sustained impact of IBSE on student motivation and conceptual knowledge acquisition and found that when guided laboratory tasks (rather than only structured inquiry) are implemented, motivation and knowledge gains persist over time. These findings underscore that simply introducing inquiry methods is insufficient without robust design, sustained engagement, and alignment with cognitive challenges appropriate to young learners. They therefore reinforce the argument

that for primary classrooms in India to realize IBSE's benefits, professional development, contextual adaptation and ongoing support are critical considerations.

Another strand of recent literature emphasises the importance of culturally responsive pedagogy in science education, especially in diverse and multilingual contexts. For example, research in South Asia and beyond has begun to examine how aligning science teaching with students' lived cultural knowledge can enhance both participation and conceptual understanding. A systematic review noted significant gaps in teacher training and resource allocation when implementing culturally inclusive teaching in elementary contexts. Moreover, an empirical study focused on culturally relevant science teaching (CRST) found positive connections between culturally grounded pedagogy and student outcomes, albeit with large variability depending on teacher capacity and institutional support. These findings highlight that while IBSE offers the pedagogical framework, without embedding it in culturally relevant content and practice—especially in multilingual Indian primary schools the full potential of science education may remain unrealised. Therefore, combining inquiry-based approaches with culturally responsive strategies appears to be a promising direction for elevating science learning equity and effectiveness.

This study offers a unique contribution by specifically focusing on the primary school level in India — a domain that has received relatively little attention in research on inquiry-based science education (IBSE), which has largely concentrated on secondary education and teacher training. For example, a recent review by Strat (2024) examined 142 empirical studies on IBSE in teacher education but noted that only a few explicitly address the primary school context in India. In addition, research on culturally responsive teaching (CRT) in science education highlights the importance of local contextualization and integrating children's cultural backgrounds into science learning (Petri, 2025). By combining these three elements IBSE, primary-level science education, and cultural responsiveness this study constructs a new framework that is especially relevant to the linguistically and resource-diverse context of Indian primary schools. It thus fills a critical gap between national education policies and classroom practices, offering a more holistic and context-sensitive approach.

The study's novelty also lies in its research design, which emphasizes the integration and contextual adaptation of IBSE methods to local Indian conditions, including both urban and rural school environments. It further connects these approaches to variables such as teacher readiness, classroom resources, and language diversity. For instance, Bernier (2025) found that only a small number of teacher training programs in CRT at the primary level effectively incorporate cultural elements into science teaching. This study advances the field by mapping moderating factors such as socioeconomic status and language of instruction in implementing IBSE for young learners in India. As a result, the findings aim to go beyond theory and offer practical implications for policymakers, curriculum developers, and teacher educators operating in under-researched real-world settings.

This research holds considerable global relevance as it addresses persistent challenges in primary science education that extend beyond the Indian context. Inquiry-based science education (IBSE) and culturally responsive pedagogy (CRT) are increasingly promoted worldwide to enhance student engagement, scientific literacy, and higher-order thinking skills (Petri, 2025; Bernier, 2025). By investigating how these approaches interact in multilingual and resource-varied primary school settings, the study provides insights that can inform educational strategies in other countries facing similar diversity and infrastructural constraints. The findings highlight the critical role of teacher preparedness, cultural contextualization, and curriculum adaptation in ensuring effective implementation of IBSE, serving as a model for policymakers, curriculum developers, and teacher educators globally. Moreover, the study contributes to comparative education research by offering data-driven evidence on how inquiry and cultural relevance can improve student outcomes across diverse socio-economic and linguistic backgrounds. International educators can apply these insights to enhance equity and learning effectiveness in science education, particularly in early grades. Thus, the study bridges local empirical evidence with global educational challenges, fostering cross-cultural learning and evidence-based instructional reforms. Overall, the research underscores the universal importance of integrating pedagogy, context, and culture for improved primary science education outcomes.

CONCLUSION

The present study demonstrates that inquiry-based science education (IBSE) combined with culturally responsive pedagogy (CRT) significantly enhances student engagement, conceptual understanding, and scientific curiosity in Indian primary schools (Rao & Singh, 2025; Chakraborty, 2023). Implementation effectiveness is strongly moderated by contextual factors such as teacher preparedness, classroom resources, language diversity, and socio-economic conditions (Patel et al., 2024). Schools that integrate local knowledge and vernacular language support show higher student outcomes, highlighting the critical role of culturally relevant instructional strategies. Despite policy support for IBSE and CRT, classroom realities often limit effective practice, indicating the need for sustained professional development and targeted interventions. The study reinforces the importance of bridging the gap between curriculum design and practical implementation through context-specific adaptations. Moreover, findings suggest that global educational initiatives can benefit from lessons learned in Indian primary school settings, particularly regarding pedagogy and cultural inclusivity. Overall, this research provides both theoretical and practical contributions for enhancing science education quality at the elementary level, ensuring equitable access to meaningful learning experiences. Future work should expand longitudinally to assess long-term impact and scalability across diverse contexts.

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