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Localized responses to systemic challenges: A study of primary science teaching in Bhutan

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Risposte locali a sfide sistemiche: uno studio sull'insegnamento delle scienze nella scuola primaria in Bhutan

This study explores the instructional challenges and adaptive strategies employed by primary science teachers in Bhutan. Using a qualitative phenomenological approach, the research draws on data from semi-structured interviews and classroom observations involving three teachers from government schools. Thematic analysis revealed recurring challenges in teaching abstract scientific concepts, insufficient access to visual and tactile learning materials, and difficulties in differentiating instruction in mixed-ability classrooms. However, the study also highlights significant pedagogical ingenuity, as teachers repurposed locally available materials, employed visual aids and sequencing tasks, and fostered peer collaboration to enhance student engagement and understanding. The findings contribute to the discourse on educational equity and localized curriculum delivery by documenting the lived experiences of teachers working in resource-constrained environments. The study recommends targeted professional development, investment in contextualized teaching aids, and recognition of teacher-led innovations to strengthen science education in Bhutan.

Questo studio esplora le sfide didattiche e le strategie adattive impiegate dagli insegnanti di scienze della scuola primaria in Bhutan. Utilizzando un approccio fenomenologico qualitativo, la ricerca si basa su dati provenienti da interviste semi-strutturate e osservazioni in classe che hanno coinvolto tre insegnanti delle scuole pubbliche. L'analisi tematica ha rivelato sfide ricorrenti nell'insegnamento di concetti scientifici astratti, accesso insufficiente a materiali didattici visivi e tattili e difficoltà nel differenziare l'insegnamento in classi con studenti di diverse abilità. Tuttavia, lo studio evidenzia anche una significativa ingegnosità pedagogica, poiché gli insegnanti hanno riutilizzato materiali disponibili localmente, hanno impiegato supporti visivi e proposto attività sequenziali, favorendo, così, la collaborazione tra pari per migliorare il coinvolgimento e la comprensione degli studenti. I risultati contribuiscono al dibattito sull'equità educativa e sull'erogazione di programmi di studio adattati ai contesti locali, documentando le esperienze vissute dagli insegnanti che lavorano in ambienti con risorse limitate. Lo studio raccomanda uno sviluppo professionale mirato, investimenti in supporti didattici contestualizzati e il riconoscimento delle innovazioni guidate dagli insegnanti per rafforzare l'educazione scientifica in Bhutan.

Keywords: Primary science education; Instructional challenges; Teacher agency; Pedagogical adaptation; Resource-constrained classrooms; Bhutanese education system.

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1. Introduction

Science education at the primary level is globally recognized as a cornerstone for cultivating scientific literacy, critical thinking, and problem-solving skills from an early age (Deehan, MacDonald & Morris, 2022). In Bhutan, the integration of science into the primary curriculum reflects the nation's commitment to holistic development and environmental stewardship, as outlined in its Gross National Happiness philosophy (Tshomo, 2016). However, despite curriculum reforms such as the New Approach to Primary Education (NAPE), Bhutanese educators continue to face persistent challenges in delivering effective science instruction (Childs, Tenzin, Johnson & Ramachandran, 2011).

The analyzed problem is situated within broader evidence that Bhutanese primary teachers, despite philosophical support for child-centered learning often face barriers translating these beliefs into classroom practice (Sherab & Dorji, 2013; Dorji, Jatsho & Choden, 2022a). Moreover, studies have shown that many Bhutanese teachers hold naïve epistemic beliefs about science, which can hinder inquiry-based teaching and student engagement (Dorji, Jatsho, Choden & Tshering, 2022b).

While previous research has explored curriculum development and teacher perceptions (Sherab & Dorji, 2013), there remains a critical gap in understanding how Bhutanese primary science teachers actively navigate and overcome instructional barriers (Dhendup & Sherab, 2023). Existing literature has not sufficiently documented the adaptive strategies employed by teachers nor has it examined how these practices contribute to pedagogical resilience and student outcomes (Wangdi & Tharchen, 2021).

This manuscript aims to address this gap by systematically analyzing the challenges faced by Bhutanese primary science teachers and the strategies they employ to overcome them. Drawing on qualitative data from classroom observations and teacher interviews, the study contributes to the discourse on teacher agency, curriculum contextualization, and science pedagogy.

To investigate the pedagogical realities of Bhutanese primary science education, this study centers its inquiry on the lived experiences of teachers who navigate both limitations and classroom level complexities. Guided by a qualitative approach, the research seeks to generate grounded insights into the nature of instructional challenges and the adaptive strategies educators employ. The following research questions and objectives provide the analytical framework for the study and reflect its commitment to contextual relevance, teacher agency, and educational equity.

1.1. Research questions

This research is guided by the following research question:

1. What obstacle do Bhutanese teachers encounter in delivering primary science education?
2. What pedagogical strategies do teachers employ to overcome these instructional barriers?

1.2. Objectives of the study

The study aims to fulfill the following objectives:

1. To identify and categorize the key instructional challenges faced by Bhutanese primary science teachers.
2. To document and analyze the adaptive strategies and pedagogical practices teachers use in response to these challenges.
3. To inform educational policy and professional development initiatives that support contextualized, inquiry-based science instruction in Bhutan.

2. Literature review

2.1. Contextualizing science education in Bhutan: conceptual foundations and curriculum design challenges

Science education at the primary level is globally regarded as essential for nurturing foundational scientific literacy, promoting inquiry-driven thinking, and encouraging environmental consciousness among young learners (National Research Council, 2012; Lederman & Lederman, 2014). Its objectives extend beyond cognitive development, preparing students to engage meaningfully with the natural world and participate responsibly in future scientific discourse. In Bhutan, these aims are embedded within the broader national vision of Gross National Happiness (GNH), a development philosophy that prioritizes sustainability, cultural preservation, and holistic well-being (Ura, Alkire, Zangmo & Wangdi, 2012).

Despite strong ideological alignment between the goals of primary science education and Bhutan's national ethos, empirical studies reveal persistent implementation challenges. Specifically, teachers struggle to convert curriculum intentions into effective classroom practice, particularly in rural and multigrade settings where resource constraints and learner diversity are prominent (Dorji *et al.*, 2022a).

Curricular reforms, most notably the New Approach to Primary Education (NAPE) have aimed to localize science content and promote experiential learning. However, the reality within classrooms suggests that the science curriculum remains dense, abstract, and developmentally misaligned. Studies have highlighted the heavy cognitive load placed on learners due to lexically complex content and insufficient scaffolding of scientific concepts (Dorji *et al.*, 2022a). These difficulties mirror findings from comparable educational contexts across South Asia and Sub-Saharan Africa. For example, research in Nepal and Ethiopia has documented similar tensions between curriculum abstraction and learner engagement, particularly in under-resourced schools (Mereku & Mereku, 2014). Such comparisons affirm a broader pattern: that curriculum relevance, instructional adaptability, and contextual responsiveness are pivotal in ensuring equitable access to meaningful science education.

In Bhutan's case, addressing these curriculum challenges requires more than material provision it demands pedagogical innovation, localized planning, and an acknowledgment of teacher agency within diverse instructional landscapes. Understanding how Bhutanese teachers interpret and navigate curriculum complexity is therefore a critical step toward educational reform that is both principled and practical.

2.2. Pedagogical orientations and adaptive practices in Bhutanese primary science education

The instructional practices adopted by primary science teachers in Bhutan are shaped not only by curricular structures and resource availability but also by deeper epistemic beliefs about the nature of scientific knowledge. Research indicates that many Bhutanese teachers perceive science as a fixed body of facts rather than a dynamic, inquiry-driven process (Dorji & Namgyel, 2024). These beliefs contribute to a pedagogical orientation that favors didactic instruction, where transmission of knowledge is prioritized over exploration and student-led inquiry (Dorji *et al.*, 2022b).

In a cross-sectional study involving 195 Bhutanese teachers, Dorji and Namgyel (2024) found that a majority lacked conceptual understanding of how scientific knowledge is justified, constructed, and revised. This epistemic stance results in limited engagement with constructivist methods, undermining efforts to foster critical thinking and scientific reasoning among students. Such findings align with international literature, where teacher beliefs are shown to significantly influence instructional quality and the implementation of inquiry-based learning (Anoling, Abella, Cagatao & Bautista, 2024; Capps & Crawford, 2012).

Despite these entrenched orientations, Bhutanese teachers demonstrate remarkable pedagogical resilience. Within the constraints of limited resources, large class sizes, and complex classroom dynamics, educators have crafted localized strategies that leverage cultural and environmental contexts to enhance science learning. Thinley, Chhetri & Powel (2022) document the effectiveness of place-based education, where scientific principles are taught through engagement with local landscapes, agricultural practices, and traditional ecological knowledge. This approach not only grounds abstract concepts in familiar settings but also fosters a sense of relevance and ownership among students.

Complementing this, Tshering Pem (2022) reports that play-based learning significantly improves student comprehension and participation in primary science classes. Through games, manipulatives, and exploration activities, teachers create opportunities for active learning—even in the absence of formal science kits or laboratories. These innovations are often teacher-driven, informal, and shaped by immediate classroom needs.

Taken together, these findings illuminate a dual narrative in Bhutanese primary science education: one of epistemic conservatism that constrains pedagogical openness, and another of adaptive ingenuity where teachers modify instruction in ways that reflect contextual realities. Addressing the former requires sustained professional development that reshapes teacher conceptions of science as an evolving discipline. Supporting the latter demands structural mechanisms that recognize, document, and scale teacher-led innovations through collaborative learning communities, mentoring, and curricular reform.

2.3. Resource and pedagogical constraints

Despite Bhutan's commitment to holistic and inclusive education under the framework of Gross National Happiness, systemic resource constraints continue to hinder the effective delivery of primary science education. In many cases, science instruction is limited to textbook-based delivery, which reinforces rote learning and restricts opportunities for conceptual exploration. The absence of such resources not only impedes cognitive development but also exacerbates educational inequities between urban and rural learners (Childs, Gyamtso, Tenzin, Sopromadze & Thompson, 2025).

Infrastructure disparities further compound these challenges. Schools in remote areas often lack basic facilities, including electricity, internet access, and dedicated science spaces. These limitations restrict the integration of digital learning tools and prevent the implementation of inquiry-based pedagogies that are central to modern science education. As a result, students in under-resourced schools are systematically disadvantaged in their exposure to scientific practices and processes.

Bhutan's mountainous geography and dispersed population have necessitated the widespread adoption of multigrade teaching, particularly in rural and semi-rural regions. While multigrade classrooms have expanded access to education, they present unique pedagogical challenges. Teachers are required to differentiate instruction across multiple grade levels simultaneously, manage diverse learning needs, and pace the curriculum in ways that accommodate varying developmental stages (Kivunja & Kuyini, 2015). These demands are intensified in science education, where conceptual progression and hands-on engagement are essential.

Moreover, teachers report limited training in inclusive pedagogies, which affects their ability to support students with learning differences, language barriers, or socio-emotional needs (Childs *et al.*, 2025). In the absence of targeted professional development, many educators rely on uniform instructional strategies that fail to address learner diversity. This not only undermines student engagement but also limits the effectiveness of science education as a tool for empowerment and equity. Addressing resource gaps, strengthening infrastructure, and equipping teachers with inclusive and multigrade-specific pedagogical skills are essential steps toward realizing Bhutan's vision of equitable and contextually relevant science education.

2.4. Strengthening teacher capacity and student engagement in Bhutanese science education

Teacher capacity is a critical determinant of instructional quality and student achievement in science education. In Bhutan, while educators express a strong commitment to professional growth, opportunities for sustained research engagement and collaborative learning remain limited. Wangdi and Tharchen (2021) found that teachers perceive research as beneficial for improving classroom practice and policy relevance, yet systemic barriers such as time constraints, lack of incentives, and restricted access to academic resources impede their participation. They also highlight that although teachers value inquiry and reflection, institutional structures rarely support their involvement in research or evidence-informed dialogue.

This disconnects between aspiration and opportunity has implications for pedagogical innovation. Without access to professional learning communities, mentorship, or research networks, teachers are less likely to experiment with new instructional strategies or contribute to localized knowledge production (Seden, Dorji, Yangdon, Wangmo & Rinchen, 2024). Moreover, the absence of structured platforms for sharing classroom experiences limits the scalability of successful practices and reinforces reliance on traditional, didactic methods.

Student engagement in science is closely tied to these instructional dynamics. Studies show that Bhutanese students often perceive science as abstract, difficult, and disconnected from their lived experiences (Dorji *et al.*, 2022b). This perception is shaped by curriculum design, teaching methods, and classroom climate. When science is taught primarily through rote memorization and textbook-based instruction, students struggle to find relevance and meaning in the content. As a result, motivation declines and achievement gaps widen.

However, emerging evidence suggests that experiential and inquiry-based approaches can significantly enhance student engagement and learning outcomes. Tshering Pem (2022) demonstrated that play-based and hands-on activities foster curiosity, improve comprehension, and create inclusive learning environments. Despite their promise, such approaches remain underutilized due to systemic constraints including limited resources, insufficient training, and rigid curricular expectations.

Addressing these challenges requires a dual focus: empowering teachers through meaningful professional development and redesigning science instruction to prioritize relevance, inquiry, and student agency. Institutional support for teacher-led research, collaborative planning, and reflective practice can catalyze pedagogical transformation. Simultaneously, embedding experiential learning into the curriculum and assessment frameworks can help students connect scientific concepts to their everyday lives, thereby improving both engagement and achievement.

Despite a growing body of literature on science education in Bhutan, several critical gaps remain that limit the depth, applicability, and scalability of current findings. Most notably, there is a lack of longitudinal, classroom-based research that tracks pedagogical practices and student outcomes over extended periods. Existing studies tend to rely on cross-sectional designs which offer limited insight into how instructional strategies, teacher agency, and student engagement evolve over time (Arzi, 2015; Shapiro, 2004). Furthermore, while Bhutanese teachers are known to adapt creatively to resource constraints, few studies have systematically examined how teacher agency and contextual adaptations develop across different stages of professional growth or in response to shifting curricular demands. Understanding these trajectories is essential for designing professional development programs that are responsive, sustainable, and locally grounded (Wangdi & Tharchen, 2021).

Another underexplored area is the role of multilingualism and cultural diversity in shaping science pedagogy. Bhutan's classrooms are linguistically rich and culturally varied, yet most research assumes a monolingual instructional context. This oversight neglects the cognitive and affective dimensions of learning science in a second or third language, as well as the potential for indigenous knowledge systems to enrich scientific understanding (Tshering, Matthews & Adlington, 2024).

3. Materials and methods

3.1. Research design

This study adopted a qualitative phenomenological approach to explore how Bhutanese primary science teachers experience and respond to the challenges they face in the classroom. Rather than just identifying what these educators encounter, the research focused on their own interpretations and actions, how they make sense of abstract curricula, limited resources, and mixed-ability classrooms, and how they adapt their teaching practices in response. Phenomenology was chosen because it allowed the study to foreground teachers' personal narratives and contextual reflections, offering deeper insight into the social, cultural, and institutional conditions shaping science education in Bhutan. As Van Manen (2016) argues, phenomenological inquiry helps us understand not just the events but the meaning behind them, which is especially important in educational research where teaching is deeply embedded in human interaction and lived experience.

3.2. Participant selection and sampling

Participants were selected using purposive sampling, ensuring that each teacher had direct and relevant experience teaching science at the primary level. A total of 3 primary science teachers were recruited from 3 government schools. The inclusion criteria required a minimum of one year of teaching experience in primary science. Among the participants, 2 were female and 1 were male. Their average teaching experience was 6.8 years, with a standard deviation of 2.4 years. Grade levels taught ranged from Class IV to Class VI, reflecting the typical structure of Bhutanese primary schools.

3.3. Data collection methods

Data was collected through two complementary qualitative methods: semi-structured interviews and classroom observations. Interviews provided rich insights into participants' perceptions, beliefs, and personal strategies. Researcher conducted face-to-face, each interview lasted between 50 to 60 minutes and was audio recorded with verbal consent. Open-ended questions focused on teaching challenges, resource limitations, curriculum interpretation, and personal adaptations.

To triangulate the data, classroom observations were carried out in 3 science classes using a structured observation protocol aligned with Bhutan's Professional Standards for Teachers. Observations emphasized teacher-student interaction, use of materials, engagement strategies, and contextual adaptation of content. Detailed field notes were recorded and coded soon after each session, allowing for thematic consistency across the dataset.

3.4. Data analysis approach

To analyze the qualitative data, we employed Braun and Clarke's (2006) six-phase thematic analysis framework, which offers a rigorous yet flexible approach for identifying patterns in rich, contextual narratives. The process began with familiarization, an immersive phase where interview transcripts and classroom observation notes were read repeatedly to gain a holistic sense of the data. During this phase, initial impressions and reflective memos were documented to begin sensitizing the researchers to emerging issues related to pedagogy, resource constraints, and instructional adaptation. Next, we generated initial codes inductively, capturing nuanced aspects of teachers' lived experiences, including moments of improvisation, conceptual confusion, and expressions of professional frustration. Coding was conducted manually and then refined using QDA Miner lite qualitative data analysis software, which facilitated organization, hierarchical structuring, and pattern detection across datasets. The use of software also enabled us to visualize the themes of frequency and co-occurrence, supporting the analytical rigor of the study.

In the third and fourth phases, coded excerpts were collated into preliminary thematic groupings. These included early constructs like "local resource improvisation" and "difficulty teaching abstract concepts." The researchers engaged in multiple rounds of discussion and re-coding to ensure these themes were coherent, distinct, and substantively relevant to the study's objectives. Phase five involved clearly defining and naming themes. At this stage, each theme was accompanied by illustrative quotes, classroom descriptions, and researcher commentary that clarified its scope and significance. These thematic labels, such as "Contextual ingenuity" and "Challenges in mixed-ability classrooms" were chosen not only for analytical clarity but also to honor the teachers' own language and framing of their experiences.

Finally, in phase six, we synthesized our findings into a detailed narrative that aligned with the research questions and illuminated the socio-pedagogical landscape of Bhutanese primary science education. To enhance credibility, peer debriefing sessions were held with two independent researchers who reviewed codes, challenged assumptions, and validated theme boundaries. Their input strengthened our interpretive trustworthiness and helped mitigate potential researcher bias.

3.5. Ethical considerations

All ethical protocols were observed throughout the study. Approval was granted by the Royal University of Bhutan's Research Ethics Board, and teachers were informed of their rights to participate voluntarily, withdraw at any time, and have their identities protected. Pseudonyms were assigned to all participants in both transcripts and final reporting to ensure confidentiality.

4. Results

4.1. Instructional challenges faced by teachers

The study revealed four major instructional challenges consistently encountered by Bhutanese primary science teachers. These were identified through thematic analysis of transcripts and triangulated with direct classroom observations.

4.1.1. Difficulty teaching abstract concepts

One recurring theme was the difficulty students faced in linking scientific symbols to real-world substances. As Teacher A described,

> My students often confuse the symbol and the substance. For example, they know salt, but when I say Na for sodium, they can't connect. They feel lost and confused. Even when I repeat it several times and write it on the board, they still ask but where is the salt?' They struggle to understand that Na represents something invisible, part of what makes salt. Some even think Na is a different chemical altogether. I try using examples and drawings, but it's still hard for them to understand.

This quote reflects a broader issue: students' prior knowledge is often rooted in sensory and contextual familiarity, making symbolic representations appear disconnected or unintuitive.

The teacher B introduced five chemical elements using common household items to bridge this gap. For example, salt was used to explain sodium (Na), and water for hydrogen (H). However, despite these context-based strategies, most students struggled to complete a matching worksheet, requiring constant prompting and clarification. Several continued to mix up the names and symbols, indicating weak conceptual retention and ongoing difficulty transitioning from concrete to abstract representations. Another major difficulty surfaced in understanding differences in reproduction and growth between plants and animals. Teacher C commented,

> Many students think animals and plants reproduce in the same way. Even after I show them pictures, they repeat the same confusion. They say things like 'So the seed is the baby like in animals?' It's clear they're trying to apply what they know from one context to another, but the concepts don't transfer smoothly. I explain the differences again and use diagrams to show flowering and non-flowering plants, but they still mix things up.

This misconception revealed the limitations of static visual aids, which, while helpful, were not sufficient to clarify nuanced biological distinctions.

In the classroom, students engaged in a sequencing activity using cut-out illustrations of a plant's growth stages. Although these visuals aimed to scaffold their understanding, many students reordered the stages incorrectly and conflated plant reproduction with animal life cycles. In response, the Teacher C conducted oral recaps and guided correction exercises to reinforce conceptual clarity, but the persistent errors underscored the challenge of teaching abstract biological mechanisms to young minds.

4.1.2. Limited access to teaching materials

Resource limitations emerged as a recurring and significant challenge in delivering effective science instruction across the observed classrooms. All respondents consistently cited the absence of essential teaching aids, visual tools, and science-specific materials as impediments to engaging young learners. Teacher A candidly reflected on the need to improvise:

> We don't have visual aids, no proper science kits. I bring things from home-plates, jars, even balloons to help explain concepts like air or melting. It's not ideal, but students are curious, and I want to make lessons real for them.

Another Teacher B pointed out the practical limitations of using school laboratories, noting that "the tables are too high for primary children and pose safety risks. Instead, we use safe, alternative materials for hands-on activities." In one lesson, Teacher B used stones, metal utensils, and water bottles to demonstrate solids and liquids, but had to describe gases verbally due to a lack of suitable physical representations. Students struggled to visualize the concept, asking repeated questions that revealed confusion and limited comprehension, such as "how can we know that it is made of atom", "Does the atom in the matter are stacked like a bricks in the buildings" highlighting the pedagogical gap left by the absence of tactile or visible learning resources.

Teacher C captured the broader instructional dilemma:

> Children look at the book, drawing and then at me, trying to imagine the process. It's like reading about magic but never seeing it happen. Diagrams help, but sometimes my sketches can't fully convey what they need to understand.

Through all observed lessons, teaching relied primarily on hand-drawn visuals and oral explanation, with no use of digital media or standardized educational aids. These reflections underline the critical role of tangible learning materials in science education, especially at the primary level. They also point to the resourcefulness of Bhutanese teachers who, despite systemic constraints, strive to make abstract concepts meaningful through contextual improvisation and locally sourced tools. Teacher A explains:

> I use what's around like leaves, stones, cooking pots, even old plastic bottles. When I teach about solids and liquids, I bring water from tap and let them touch it. It's not perfect, but the students light up when they see something real. That's when learning happens.

This quote shows how creative teaching with everyday items helps students grasp tricky science ideas, even without available resources.

4.1.3. Constraints in differentiation and mixed-ability settings

Teaching science in mixed-ability classrooms presented challenges in differentiation and pacing. Teacher C explained:

> Some students get things quickly, others need more examples. I can't give them all enough time when the class has mixed levels. I try giving extra support to those who fall behind, but then the fast learners lose interest and start talking or playing. It's hard to manage both ends.

This was evident in the lesson, where higher achieving students completed sequencing activities early, while others required additional guidance and repeated clarification. The teacher C and A used group questioning and simple oral comparisons, but the time allocated limited individual support.

In another case, the teacher B said: "We don't have assistants. If I try to help slow learners more, the rest get distracted. It's a struggle".

Observations confirmed limited differentiation opportunities, with group-based instruction dominating the lesson format and only brief one-on-one interaction. For instance, during a sequencing activity on plant growth stages, higher-achieving students completed the task quickly and became disengaged and distracted other, while others required repeated guidance.

4.2. Adaptive strategies employed by teachers

Despite the constraints outlined above, teachers utilized various adaptive strategies to facilitate learning, confirmed through interview comments and classroom observations.

4.2.1. Use of locally available materials

Teachers frequently replaced standard teaching aids with common household or environmental items. Teacher C shared:

> We use stones, pots, water glasses, anything visible and touchable. The students learn better when they see and touch. When we don't have proper science kits, we improvise. For solids and liquids, I bring metal plates, water bottles, and even cooking spoons. Sometimes we go outside and pick leaves or small rocks. It might not be expensive, but it works.

In the lesson on states of matter, stones, water containers, and plates were used as physical examples of solids and liquids. Students completed classification worksheets using these materials and showed higher participation during object-based tasks than during explanation-only segments.

4.2.2. Visual and sequencing techniques

To support retention and reinforce key concepts, teachers used cut-and-paste tasks, diagram drawing, and oral repetition. Teacher B commented:

> We use pictures and matching games. If they don't get science, at least the visuals help them remember. I draw diagrams on the board and give them cut-outs to arrange in order—like the life cycle of a plant. Sometimes they just memorize terms, but when they see the stages in pictures, they start to make sense. Even the quiet ones become more active they point to, they ask questions, and they help each other. It's not perfect, but visual learning gives them something to hold onto.

In the reproduction lesson, students completed plant life cycle diagrams and organized sequences through guided visuals. The compound lesson included chart repetition and matching worksheets, with symbols written on the board and repeated aloud by students.

4.2.3. Peer collaboration and group engagement

Teachers encouraged students to work in pairs or small groups. Teacher C noted: "When I group them together, some students teach each other. It reduces pressure and helps slow learners catch up".

In the lesson, students sorted objects together and discussed their classifications. Observation revealed that higher-performing students supported peers during worksheet completion. Teachers monitored group activity and offered clarification when needed.

4.3. Findings in relation to research objectives

This study revealed a layered picture of what it means to teach science in Bhutanese primary classrooms. On one hand, teachers face real and recurring challenges like the difficulty of making abstract concepts accessible to young learners, the lack of teaching materials and the pressures of mixed-ability classrooms. These are not just logistical hurdles; they affect how students connect with science and how teachers feel about their own practice. But just as clearly, the data showed how teachers aren't just passive recipients of these constraints. They respond with ingenuity and care repurpose everyday items as teaching tools, anchoring science in culturally familiar examples, relying on visuals to aid memory, and fostering peer support when individual help isn't possible. These adaptive strategies don't just fill gaps they reflect a deep local way of making science meaningful.

Together, these findings offer more than just a snapshot of classroom challenges. They give us insight into the practical wisdom of teachers operating in resource-limited and culturally diverse contexts. That wisdom deserves to be part of future reforms, whether we are talking about curriculum design, professional development, or how we define effective science education itself.

4.4. Discussion

The findings of this study reaffirm and deepen our understanding of the instructional barriers Bhutanese primary science teachers contend with particularly when dealing with abstract scientific concepts. Teachers consistently described how limited access to visual aids and contextual materials made these topics difficult to convey to young learners. These observations echo previous research by Dorji *et al.* (2022b), which highlighted how educators often hold static, content-centered views of science that hinder their ability to translate complex ideas into age-appropriate instruction. This study also observed a strong reliance on textbook-based teaching and verbal explanation. They described Bhutan's primary science curriculum as overly dense, lacking developmental progression, and rarely scaffolded for gradual conceptual understanding. Similarly, the limited presence of inquiry-based learning or hands-on experimentation in classroom practice aligns with findings by Childs *et al.* (2011), who described Bhutan's science curriculum as fragmented and overly prescriptive, offering little room for flexibility or exploration.

Yet this research goes a step further by documenting teachers' adaptive efforts responses not just born out of necessity but marked by creativity and commitment. In classrooms with few formal materials, teachers used familiar, locally available items such as stones, jars, leaves, and cooking utensils to make scientific principles visible and tangible. Cultural analogies helped students relate concepts to their everyday lives, for example, connecting sodium to the salt used in family meals, or explaining germination through backyard planting traditions. These strategies reflect a form of pedagogical resilience where teachers draw on contextual wisdom to bridge systemic gaps.

While Thinley *et al.* (2022) and Tshering Pem (2022) have discussed the benefits of place-based and play-based science learning, this study provides real-time classroom evidence of such practices in action. It shows how educators improvise, reinterpret curriculum, and recalibrate their teaching to keep students engaged even in the absence of ideal conditions. These findings enrich the growing discourse on teacher agency and classroom innovation in resource-constrained settings, and point toward the need for reforms that support, rather than suppress, localized pedagogical ingenuity.

4.5. Implications of the findings

The findings from this study have significant implications for education policy, curriculum design, and teacher professional development in Bhutan's primary science education system.

4.5.1. Curriculum reform

The consistent difficulty teachers experience when delivering abstract scientific content especially in areas such as chemical elements and biological processes, highlights the need for curricular revision. Prior studies, including those by Dorji *et al.* (2022a), describe the Bhutanese science curriculum as lexically dense and developmentally misaligned. To address this, curriculum developers should prioritize contextualization and inquiry-driven approaches by embedding local examples, hands-on activities, and culturally relevant materials that resonate with students lived experiences (Tenzin & Maxwell, 2008; Thinley *et al.*, 2022).

4.5.2. Teacher professional development

The observed reliance on didactic teaching methods and limited incorporation of visual aids and active learning strategies points to gaps in pedagogical training. Dorji *et al.* (2022b) note that Bhutanese teachers often hold static views of science, which limits their application of constructivist methods. Targeted professional development should equip teachers with skills for improvisation, differentiation, and inclusive instruction (Childs *et al.*, 2025; Sherab & Schuelka, 2019). Additionally, mentorship models and peer-led learning communities could foster sustained pedagogical growth.

4.5.3. Resource allocation

Systemic shortages in teaching materials ranging from science kits to visual aids remain a major barrier to effective instruction. Policymakers should consider investing in cost-effective experimental tools and support community-driven initiatives, such as co-creating educational resources with locals and parents, to increase the availability of culturally relevant materials (Tshering Pem, 2022; Thinley *et al.*, 2022).

4.5.4. Pedagogical innovation

Despite these constraints, the study revealed teachers' capacity to implement learner-centered practices such as group work, peer instruction, and visual sequencing tasks. These innovations not only reflect pedagogical resilience but also align with inclusive and participatory models of science education recommended by global frameworks (Lederman & Lederman, 2014). Systematic recognition and support for such grassroots adaptations through documentation, mentorship, and policy endorsement can help scale the best practices across the education system.

While the study is situated in Bhutan, its findings have broader relevance for science education in other low-resource and culturally diverse contexts. The challenges of curriculum abstraction, resource scarcity, and pedagogical limitations are common across many developing countries (Mereku & Mereku, 2014). The adaptive strategies documented here particularly contextualization and improvisation may inform teacher support models in similar settings.

4.6. Strengths and limitations of the study

This study presents notable strengths by integrating both interview and observational data, thereby enhancing its validity through methodological triangulation. It captures real-time classroom practices, providing granular insights into teacher behavior. Additionally, the focus on under-researched eastern districts of Bhutan adds a valuable geographic dimension to the literature, addressing a gap in regional representation.

However, the study's scope is constrained by certain limitations. The small sample size, limited to three interviews and three classroom observations, may not adequately reflect broader national trends. Lastly, the brief observational window may have omitted longitudinal shifts in instructional strategies, limiting the depth of analysis regarding adaptive teaching practices over time.

Future research could expand the sample across multiple districts and include longitudinal classroom observations. Incorporating student perspectives and learning outcomes would also strengthen the analysis. Mixed-method designs combining qualitative and quantitative data could offer a more comprehensive understanding of instructional efficacy.

5. Conclusion

This study explored the instructional challenges faced by Bhutanese primary science teachers and the adaptive strategies they employ to mitigate these barriers. Drawing from interview narratives and classroom observations, the research revealed consistent difficulties in teaching abstract scientific concepts, limited access to instructional materials, and pedagogical constraints in mixed-ability settings. Despite these challenges, teachers demonstrated notable resilience by improvising with locally available resources, contextualizing lessons through culturally familiar references, and employing visual and collaborative learning techniques.

These findings contribute to a deeper understanding of pedagogical realities in resource-constrained environments and affirm the importance of context-sensitive adaptations. The study underscores the urgent need for curriculum reform, improved resource provision, and teacher professional development that supports inquiry-based and inclusive science instruction.

While limited in geographic scope and sample size, the study offers valuable insight into localized strategies that enhance student engagement and conceptual understanding. Future research should expand across districts, incorporate student learning data, and explore longitudinal patterns of instructional adaptation.

References

Anoling, K. M., Abella, C. R. G., Cagatao, P. P. S., & Bautista, R. G. (2024). Critical perspectives, theoretical foundations, practical teaching, technology integration, assessment and feedback, and hands-on practices in science education. *American Journal of Educational Research*, *12*(1), 20–27. https://doi.org/10.12691/education-12-1-3

Arzi, H. J. (2014). Longitudinal Studies in Science Education. In *Springer eBooks* (1–5). https://doi.org/10.1007/978-94-007-6165-0_512-3

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Capps, D. K., & Crawford, B. A. (2012). Inquiry-Based instruction and teaching about nature of science: Are they happening? *Journal of Science Teacher Education*, *24*(3), 497–526. https://doi.org/10.1007/s10972-012-9314-z

Childs, A., Gyamtso, D., Tenzin, W., Sopromadze, N., & Thompson, I. (2025). A study of teacher quality in Bhutan: issues and challenges for initial teacher education and continuing professional development. *Asia-Pacific Journal of Teacher Education*, 1–27. https://doi.org/10.1080/1359866x.2025.2478860

Childs, A., Tenzin, W., Johnson, D., & Ramachandran, K. (2011). Science Education in Bhutan: Issues and challenges. *International Journal of Science Education, 34*(3), 375–400. https://doi.org/10.1080/09500693.2011.626461

Deehan, J., MacDonald, A., & Morris, C. (2022). A scoping review of interventions in primary science education. *Studies in Science Education*, *60*(1), 1–43. https://doi.org/10.1080/03057267.2022.2154997

Dhendup, S., & Sherab, K. (2013). *Exploring Bhutanese Primary School Teachers' Technological Knowledge*. Digital Commons @ University of South Florida. https://digitalcommons.usf.edu/jger/vol7/iss2/2/

Dorji, K., & Namgyel, T. (2024). Bhutanese primary science teachers' epistemic beliefs of science. *Science & Education*, *34*, 3389–3406. https://doi.org/10.1007/s11191-024-00563-7

Dorji, K., Jatsho, S., & Choden, P. (2022a). Issues of Bhutanese science curriculum: A view from the exploratory study. *RABSEL*, *22*(2). https://doi.org/10.17102/rabsel.22.2.5

Dorji, K., Jatsho, S., Choden, P., & Tshering, P. (2022b). Bhutanese science teachers' perceptions of the nature of science: a cross-sectional study. *Disciplinary and Interdisciplinary Science Education Research*, *4*(1). https://doi.org/10.1186/s43031-021-00044-9

Durrani, N., & Nawani, D. (2020). Knowledge and curriculum landscapes in South Asia. In *Global education systems* (1–31). https://doi.org/10.1007/978-981-13-3309-5_53-1

Kivunja, C., & Kuyini, A. B. (2015). Investigating the gaps among policy, teacher education, and practice in multigrade education in Bhutan. *International Journal of Educational Reform*, *24*(2), 116–135. https://doi.org/10.1177/105678791502400204

Lederman, N. G., & Lederman, J. S. (2014). Research on teaching and learning of nature of science. In S. K. Abell, & N. G. Lederman (Eds.), *Handbook of Research on Science Education, Volume II* (pp. 600–620). Routledge. https://www.taylorfrancis.com/books/9780203097267

Mereku, D. K., & Mereku, C. W. K. (2014). Congruence between the intended, implemented, and attained ICT curricula in Sub-Saharan Africa. *Canadian Journal of Science Mathematics and Technology Education*, *15*(1), 1–14. https://doi.org/10.1080/14926156.2014.992555

National Research Council (2012). A framework for K-12 science education. In *National Academies Press eBooks*. https://doi.org/10.17226/13165

Seden, K., Dorji, T., Yangdon, Y., Wangmo, K., & Rinchen, S. (2024). *Scaling Teacher Professional Development in Bhutan*. Geneva: NORRAG / KIX EMAP Hub. Retrieved from https://www.gpekix.org/sites/default/files/webform/submit_to_the_library/760/scaling-teacher-professional-development-in-bhutan-english.pdf

Shapiro, B. (2004). Exploring a Lngitudinal study of science education. In *Research in Science Education*, *34*(1), 1–27.

Sherab, K., & Dorji, P. (2013). Bhutanese teachers' pedagogical orientation in the primary classes: A factor on quality education. *Journal of International Society for Teacher Education (JISTE)*, *17*(1), 17–25.

Tenzin, W., & Maxwell, T. W. (2008). *Primary Science Curriculum in Bhutan: Development and Challenges* (pp. 313–332). https://doi.org/10.1163/9789087902490_027

Thinley, J., Chhetri, P. B., & Powel, B. B. (2022). Impact of place-based education as teaching pedagogies for active engagement of sixth grade students in learning science. *Journal on School Educational Technology*, *18*(1), 19–25. https://eric.ed.gov/?id=EJ1361335

Tshering Pem. (2022). *The Application of Play-based Learning for A Science Subject of Grade 5 Bhutanese Students* [Master's thesis, Rangsit University]. https://rsuir-library.rsu.ac.th/bitstream/123456789/2158/2/TSHERING%20PEM.pdf

Tshering, T., Matthews, J., & Adlington, R. (2024). Bhutanese Teacher Educators' Attitudes Towards Information, Communication and Technology Acceptance and use in Teaching. *Australian and International Journal of Rural Education*, *34*(3), 36–54. https://doi.org/10.47381/aijre.v34i3.750

Tshomo, P. (2016). Conditions of happiness: Bhutan's Educating for Gross National Happiness Initiative and the Capability approach. In *Education in the Asia-Pacific region* (pp. 139–152). https://doi.org/10.1007/978-981-10-1649-3_9

Ura, K., Alkire, S., Zangmo, T., & Wangdi, K. (2012). *An Extensive Analysis of Gross National Happiness Index*. The Centre for Bhutan Studies. https://ophi.org.uk/publications/Extensive-GNH-2012

Van Manen, M. (2016). *Phenomenology of Practice*. Routledge eBooks. https://doi.org/10.4324/9781315422657

Wangdi, T., & Tharchen, N. (2021). Bhutanese school teachers' perceptions, challenges, and perceived benefits in doing research. *Issues in Educational Research*, *31*(3), 990–1005. https://www.iier.org.au/iier31/wangdi-abs.html

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