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BETWEEN POLICY AMBITION AND CLASSROOM REALITY: A CRITICAL REVIEW OF STEM EDUCATION IN ARUNACHAL PRADESH, INDIA

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ABSTRACT

The National Education Policy (NEP) 2020 and the state-level 'Mission Shikshit Arunachal 2029' commit Arunachal Pradesh, a sparsely populated Himalayan border state with a predominantly Scheduled Tribe school population, to an ambitious, technology-intensive transformation of science, technology, engineering and mathematics (STEM) education. This review triangulates four evidence streams: policy documents; official administrative statistics (UDISE+ 2023–24 and 2024–25; ASER 2024); documentation of STEM interventions operating in the state (Atal Tinkering Labs, IBM STEM for Girls, Digi-Kaksha, merit scholarships and mathematics enrichment camps, including the 2026 Mathematical Thinking Camp at Pasighat); and two supervised undergraduate field studies in East Siang district on vendor numeracy and on student attitudes to AI-assisted instruction. Read through situated cognition, the multi-level digital divide and the experimental literature on educational technology, the evidence reveals a three-fold gap between policy and practice: infrastructural (33.6% of schools with internet against 63.5% nationally), organisational (a favourable pupil-teacher ratio of 13:1 coexisting with 562 single-teacher schools) and pedagogical (abstract classroom mathematics divorced from the robust situated numeracy documented in local markets). A 'pedagogy-first, technology-second' strategy with offline-capable tools, contextualised curriculum, and sustained teacher professional development offers the most credible route to the state's stated goals, judged against measurable learning indicators rather than installed inputs.

HIGHLIGHTS

- Mission Shikshit Arunachal 2029 commits a tribal-majority Himalayan border state to a technology-intensive STEM reform, yet only 33.6% of its schools report internet access against the national average of 63.5%.
- A favourable aggregate pupil-teacher ratio of 13:1 coexists with 562 single-teacher schools and 22.2% of schools enrolling ten or fewer pupils, exposing a teacher-distribution problem that aggregates conceal.
- Local field evidence from Pasighat markets replicates the Carraher-Nunes-Banerjee result: vendors solve concrete arithmetic fluently yet struggle with its abstract school form, and transfer fails in both directions.

KEYWORDS: STEM education mathematics education National Education Policy 2020 Mission Shikshit Arunachal 2029 digital divide situated cognition educational technology teacher professional development Northeast India Arunachal Pradesh.

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1. INTRODUCTION

India confronts what the World Bank has termed a learning crisis: enrolment is near universal, yet learning outcomes lag far behind curricular expectations. Nationally representative assessments indicate that fewer than a third of rural children in Standard V can solve a basic division problem, even after a decade of measurement and despite recent post-pandemic recovery (ASER Centre, 2025; Muralidharan & Singh, 2021). The National Education Policy (NEP) 2020 responds to this crisis by placing universal foundational literacy and numeracy (FLN) at the centre of reform and by calling for a decisive pedagogical shift away from rote learning (Government of India, 2020). How this national agenda plays out in India's most remote and infrastructurally constrained states, however, remains poorly documented in the research literature. Most empirical work on Indian school reform draws on large, comparatively accessible states; the specific conditions of the north-eastern Himalayan periphery are rarely examined (Jamoh, 2025; Meto & Tok, 2025).

Arunachal Pradesh presents an instructive and understudied case. The state's school system is small in absolute terms: 3,229 schools, 319,826 enrolled students and 25,117 teachers in 2024–25, but it operates across some of the most difficult terrain in the country, and 72.7% of its enrolled students belong to Scheduled Tribes, the highest such proportion among Indian states after Mizoram, Lakshadweep and Ladakh (Ministry of Education, 2025). The state government has articulated an unusually explicit reform agenda. 'Mission Shikshit Arunachal 2029', approved by the state cabinet in February 2025 and presented to the Legislative Assembly the following month, sets time-bound targets that include universal FLN in Grades 1-3, smart classrooms and internet connectivity in at least 80% of government schools, and the elimination of single-teacher schools (Arunachal24, 2025a; Elets Digital Learning, 2025). The mission is embedded in the broader 'Viksit Arunachal 2047' framework, which mirrors the national 'Viksit Bharat 2047' vision; in August 2025, the Chief Minister announced five 'transformative pledges' (*Panch Pratigya*) for the state, listing universal access to quality education first among them (United News of India, 2025). Infrastructure spending has followed: foundation stones for education projects worth Rs 750 crore were laid in the 2025–26 financial year (Arunachal24, 2025b), and as of mid-2026, the mission's emphasis on foundational learning and secondary-level performance remains a stated government priority (IANS, 2026).

Whether these commitments can translate into improved STEM learning is an open question, with implications beyond Arunachal Pradesh for other low-density, low-connectivity regions attempting technology-led educational reform. The international evidence gives grounds for caution. Large-scale distribution of hardware without accompanying pedagogical change has repeatedly failed to improve academic outcomes, most prominently in the One Laptop per Child programme in Peru (Cristia et al., 2017), whereas technology deployed as a complement to instruction, particularly software that adapts to the learner's actual level, has produced some of the largest measured gains in developing-country education (Escueta et al., 2020; Muralidharan et al., 2019). Within India, Muralidharan and Singh (2021) document how reforms can be judged successful on the basis of completed paperwork and installed inputs even when management, pedagogy and learning remain unchanged. A state that sets infrastructural targets therefore risks achieving the measurable means of reform without its pedagogical ends.

This article examines that risk for Arunachal Pradesh. We address three questions. First, how closely do the state's policy commitments align with documented infrastructural and human-resource conditions in its schools? Second, what design features distinguish the STEM interventions currently operating in the state, and what do these features imply for scalability in a low-connectivity environment? Third, what do locally generated field data - specifically, two supervised undergraduate studies of market-vendor numeracy and of student attitudes towards AI-assisted instruction suggest about the pedagogical assumptions underlying current policy?

The article makes three contributions. It provides, to our knowledge, the first critical synthesis of STEM education policy, administrative data and field evidence for Arunachal Pradesh, updated to the UDISE+ 2024–25 reporting cycle and to initiatives operating in the state through the first half of the

2026–27 academic year, including the 5-day residential Mathematical Thinking Camp held at Jawaharlal Nehru College, Pasighat, in September-October 2026. It connects small-scale local findings to two substantial international literatures: the psychology of situated or 'street' mathematics (Banerjee et al., 2025; Carraher et al., 1985; Nunes et al., 1993) and the multi-level conception of the digital divide (Hargittai, 2002; van Dijk, 2006; Warschauer, 2003) - thereby giving local observations a theoretical anchoring they would otherwise lack. Finally, it derives from this synthesis a set of implementable design principles and measurable indicators for STEM reform in comparable low-resource settings.

The remainder of the article is organised as follows. Section 2 sets out the conceptual framework and the review method. Section 3 summarises the policy context. Sections 4 and 5 present the documentary findings on system capacity and on the intervention landscape. Section 6 synthesises the field evidence. Section 7 discusses implications, identifies research gaps and sets out recommendations. Section 8 states the limitations of the review, and Section 9 concludes.

2. CONCEPTUAL FRAMEWORK AND REVIEW METHOD

2.1 Review design and evidence streams

This article reports a mixed-methods critical analysis combining documentary review with the structured synthesis of two locally conducted field studies. Following the approach common in education-policy analysis, we triangulate heterogeneous sources against an explicit conceptual framework and grade our confidence in each claim by the quality of its source.

Four evidence streams were drawn upon. (a) *Policy documents.* NEP 2020 (Government of India, 2020), the NIPUN Bharat guidelines (Department of School Education and Literacy, 2021), the Right of Children to Free and Compulsory Education (RTE) Act norms (Government of India, 2009), the guidelines of the Arunachal Pradesh Scholarship for Academic Excellence (Directorate of Higher and Technical Education, 2024) and the publicly reported structure and targets of Mission Shikshit Arunachal 2029 (Arunachal24, 2025a; Education Times, 2025; Elets Digital Learning, 2025). (b) *Administrative statistics.* Quantitative indicators are drawn from the official UDISE+ reports for 2023–24 and 2024–25 (Ministry of Education, 2024, 2025) and from the ASER 2024 rural survey (ASER Centre, 2025). Following the Ministry of Education's caveat, we treat UDISE+ figures from 2022–23 onwards as internally comparable but not strictly comparable with earlier school-aggregated rounds (Ministry of Education, 2025). All percentages for Arunachal Pradesh in Section 4 were computed by the authors from the state-wise tables of the 2024–25 report. (c) *Programme documentation and press reports.* For the intervention audit in Section 5, we relied on official programme documentation where available (Atal Innovation Mission, 2025; Directorate of Higher and Technical Education, 2024; IBM Newsroom, 2022) and on press reports for facts not otherwise documented, each flagged in the text. (d) *Field studies.* Two undergraduate dissertations completed in 2025 at Jawaharlal Nehru College, Pasighat, under the supervision of the first author, provide ground-level evidence (Panggam, 2025; Podo, 2025); their scope and limitations are detailed in Section 2.5.

2.2 Integrated STEM education and foundational numeracy

STEM education is not a settled construct. Reviews of the field distinguish between the mere co-presence of the four disciplines and genuinely integrated approaches in which scientific, technological, engineering and mathematical practices are brought to bear on authentic problems (Bybee, 2010; English, 2016; Honey et al., 2014; Martín-Páez et al., 2019). Kelley and Knowles (2016) conceptualise integrated STEM as situated learning organised around engineering design and scientific inquiry, a framing that presupposes two conditions frequently absent in low-resource systems: teachers confident enough to orchestrate open-ended investigation, and learners with secure foundational numeracy on which higher-order practices can build. In the Indian policy context, the operative foundation is FLN, the explicit first goal of NEP 2020 and of the NIPUN Bharat mission (Department of School Education and Literacy, 2021; Government of India, 2020). Any assessment of STEM prospects in an Indian state must therefore attend as much to foundational mathematics as to laboratories and robotics kits.

2.3 Situated cognition and street mathematics

A second strand of the framework concerns where and how mathematical competence develops. The situated-cognition tradition holds that knowledge is bound up with the activity and context in which it is acquired (Kolb, 1984; Lave & Wenger, 1991). Its most striking empirical expression is the 'street mathematics' research programme initiated in Brazilian markets, which showed that young vendors solved proportion and arithmetic problems fluently in commercial contexts yet failed formally identical problems presented in school format (Carraher et al., 1985; Nunes et al., 1993). The ethnomathematics literature generalises the point: mathematical practice is culturally embedded, and school mathematics is one practice among several rather than the sole legitimate form (D'Ambrosio, 1985).

Recent large-scale evidence from India has sharpened this picture in a policy-relevant way. Surveying 1,436 children working in the markets of Kolkata and Delhi, Banerjee et al. (2025) found that working children performed complex mental arithmetic effectively at their stalls and on hypothetical market problems, but could not solve abstract problems of equal or lesser difficulty in the format used at school; conversely, schooled non-working children solved abstract problems but performed poorly on applied market problems. Transfer failed in *both* directions. Related experimental work shows that early interventions can durably enhance intuitive mathematics without improving formal mathematics (Dillon et al., 2017). The implication for curriculum design is not that informal mathematics should replace formal instruction - working children's intuitive skills did not rescue their school performance - but that instruction must deliberately build bridges between concrete, situated competence and abstract, symbolic fluency. This is precisely the pedagogical bridge that NEP 2020's call for experiential learning gestures towards, and it supplies the analytic lens through which we read the vendor-numeracy study synthesised in Section 6.

2.4 The digital divide as a layered phenomenon

The third strand concerns technology. Early digital-divide research focused on binary access; subsequent work established that access is only the first of several layers. Hargittai (2002) documented a 'second-level' divide in skills among those with nominally equal access, and van Dijk (2006) systematised the divide into successive barriers of motivation, physical access, skills and usage. Warschauer (2003) reframed the policy problem as one of social inclusion: meaningful use of technology depends on the surrounding ecology of human and social resources, not on devices alone. On this view, a policy that counts smart classrooms measures only the second of four layers.

The experimental economics of education reaches a complementary conclusion. Hardware-distribution programmes without pedagogical integration have generally produced null effects on learning (Cristia et al., 2017), whereas computer-assisted learning that adapts to the student's actual preparation level has produced large gains precisely because most students in developing-country classrooms are far behind curricular expectations (Escueta et al., 2020; Muralidharan et al., 2019). Teaching-at-the-right-level interventions achieve similar results without technology (Banerjee et al., 2017). The consistent lesson is that technology functions as a complement to, not a substitute for, effective instruction a proposition that, as we show below, the students of Arunachal Pradesh articulate unprompted.

2.5 Field studies: provenance, scope and ethics

The two field studies form part of a nine-student cohort project on the common theme 'Mathematical Motivation, Competency and Technology Impact', in which B.Sc. students shared a pooled interview base of approximately 200 respondents (school students and market vendors in East Siang district and adjoining areas) but pursued distinct sub-questions with individually collected data. The first study (Panggam, 2025) examined the everyday mathematics of 50 market vendors in Pasighat: vegetable sellers, meat sellers, grocers, and shop owners of varied educational backgrounds recruited by convenience sampling in the town's markets. Data collection began with a written questionnaire but shifted, for reasons discussed in Section 6.1, to informal conversational interviews. The second study (Podo, 2025) surveyed school students from Classes V to XII in East Siang on their experience of, and preferences among, traditional instruction, AI-assisted learning and hybrid models, combining a structured preference item with classroom observation and open group discussion.

Both studies obtained verbal informed consent; no personally identifying information is reported. The dissertations are openly archived on Zenodo. We emphasise their evidentiary status at the outset: they are small, non-random, single-district studies conducted by undergraduate researchers under faculty supervision. We use them not to estimate population parameters but as structured local observations whose value lies in their convergence, or otherwise, with well-established international findings. One factual point in Section 5 - the composition of the STEM acronym in a scholarship notification - was clarified through direct communication with the office of the Education Commissioner, Government of Arunachal Pradesh (personal communication, 24 July 2025).

2.6 Analytic approach

Documentary and field materials were read against the three strands of the conceptual framework. For each policy target we asked what layer of the digital divide it addresses and what its implicit theory of learning is; for each intervention we coded its dependence on connectivity, its unit cost structure so far as documented and its human-capital component; and for each field finding we asked whether it replicates, refines or contradicts the international evidence. Discrepancies between administrative sources, for example, between Assembly-reported and UDISE+ school counts, are reported rather than suppressed, since data-system reliability is itself a finding relevant to a mission premised on 'data-driven governance'.

3. THE POLICY CONTEXT

NEP 2020 is the first comprehensive revision of Indian education policy since 1986. Its stated pedagogical ambition is a system that is 'experiential, holistic, integrated, inquiry-driven, discovery-oriented, learner-centered, discussion-based, flexible' and enjoyable, prioritising conceptual understanding and critical thinking over rote procedure (Government of India, 2020). Scholarly assessments have welcomed the policy's diagnosis, particularly its recognition that gains in schooling have not produced gains in learning while cautioning that the document specifies ends far more clearly than implementable means, and that Indian reform history is replete with initiatives judged successful on administrative compliance rather than on outcomes (Muralidharan & Singh, 2021).

Mission Shikshit Arunachal 2029 is the state's vehicle for operationalising NEP 2020. Developed after a six-month groundwork phase of district visits and community consultations, and approved by the cabinet in February 2025, the mission is organised around four pillars: enhancing learning outcomes, optimising human resources, strengthening educational infrastructure and building teacher capacity (Arunachal24, 2025a; Elets Digital Learning, 2025). Its headline targets are specific and time-bound: universal FLN in Grades 1-3; internet connectivity and smart classrooms in at least 80% of government schools; the elimination of single-teacher and near-zero-enrolment schools through rationalisation and inter-village school models; and competency-based teaching across Grades 1-12 (Arunachal24, 2025a; Education Times, 2025). As presented to the Legislative Assembly in March 2025, the state system then comprised 3,496 schools across 28 districts with about 2.72 lakh enrolled students and 23,224 teachers, of whom 10,011 were regular and 5,391 contractual (Education Times, 2025); we return below to the discrepancies between these figures and UDISE+ data.

Two features of this policy architecture deserve emphasis. First, the mission's measurable targets are overwhelmingly infrastructural and organisational connectivity percentages, school counts, and teacher ratios, whereas its pedagogical goals (competency-based learning, experiential methods) lack comparably concrete indicators. Second, the mission explicitly embraces school consolidation: closure or merger of non-functional and zero-enrolment schools is a stated instrument, not an embarrassment (Arunachal24, 2025b). Both features create the conditions for what may be called an implementation paradox: the targets easiest to verify are those least directly connected to learning, so a mission can be certified as advancing while the pedagogical transformation that NEP 2020 envisages as its purpose remains unmeasured. The national evidence that completed paperwork and installed inputs can substitute for actual change in classrooms (Muralidharan & Singh, 2021) makes this more than a hypothetical risk.

4. THE SYSTEM AS IT STANDS: INFRASTRUCTURE AND HUMAN RESOURCES

4.1 Digital readiness

Table 1 presents the state's core digital-readiness indicators against national averages, computed from the two most recent UDISE+ reports. The gaps are large and persistent. In 2024–25, exactly one third of schools in Arunachal Pradesh (33.6%) reported an internet facility, against a national average of 63.5%; 47.7% reported a computer facility of any kind (national: 64.7%), and only 42.0% reported computers functional for pedagogical purposes. Functional electricity was reported by 62.3% of schools against 91.9% nationally. Year-on-year movement is modest and mixed: computer and internet coverage improved by roughly four to five percentage points, while the reported functional-electricity share declined, a movement that may reflect reporting changes as much as physical deterioration and that we therefore interpret cautiously. The subsequent UDISE+ 2025-26 round, released on 7 July 2026 after the analysis reported here was completed, shows the national internet-access figure moving further to 67.4%, which widens rather than narrows the state–national gap unless state-level progress has outpaced it (Ministry of Education, 2026).

Table 1. Digital readiness of schools: Arunachal Pradesh and India.

Indicator (% of schools)	AP 2023-24	AP 2024-25	India 2024-25
Functional electricity connection	68.8	62.3	91.9
Computer facility	42.6	47.7	64.7
Functional computers for pedagogy	–	42.0	57.9
Internet facility	30.5	33.6	63.5

Note. Computed by the authors from the state-wise infrastructure tables of the UDISE+ reports (Ministry of Education, 2024, 2025). UDISE+ cautions that indicators from 2022–23 onwards are not strictly comparable with earlier rounds; the 2023–24 column is shown for orientation only. A dash indicates the indicator was not separately tabulated in that round.

These figures bear directly on Mission Shikshit's target of internet-equipped smart classrooms in 80% of government schools by 2029: the state must roughly double, and then some, its internet coverage within the mission period, in terrain where the marginal school to be connected is by construction the most remote. Expansion of the BharatNet backbone into the state has been reported and is a genuine enabling development (Hindustan Times, 2025), but the divide framework of Section 2.4 predicts - and the field evidence below confirms - that physical connectivity is only the first layer of the problem. Household-side constraints are equally binding: participants in the school study cited the unaffordability of devices f or families below the poverty line as a first-order objection to technology-led instruction (Podo, 2025), and the skills layer is attested by regional studies finding low digital literacy among both teachers and students (Jamoh, 2025; Meto & Tok, 2025).

4.2 Enrolment pipeline

Table 2 shows gross enrolment ratios (GER) by level. Arunachal Pradesh enrols generously at the primary level, with a GER above 100 indicating over- and under-age enrolment, but the pipeline narrows sharply thereafter, falling to 69 at secondary and 44 at higher secondary, both well below national averages. Official dropout rates tell the same story, reaching 18.3% at the secondary level against 11.5% nationally (Mehta, 2025; Ministry of Education, 2025). For STEM specifically, the higher-secondary constriction is critical: it is at this stage that students formally elect science and mathematics streams, so the state's future STEM cohort is being determined by retention failures that precede any question of laboratory quality. Only 18.1% of the state's teachers serve at the higher-secondary level, the lowest share among all states and union territories (Ministry of Education, 2025).

Table 2. Gross enrolment ratio by level of school education, 2024–25.

Level	Arunachal Pradesh	India
Primary	113	90.9
Upper primary	87	90.3
Secondary	69	78.7
Higher secondary	44	58.4

Note. Source: UDISE+ 2024–25 (Ministry of Education, 2025). GER above 100 indicates enrolment of over- or under-age children relative to the level-appropriate age band.

4.3 The teacher-deployment paradox

On the crudest measure, the state is teacher-rich. Its pupil-teacher ratio (PTR) of 13:1 is among the most

favourable in India and far inside the RTE norms of 30:1 (primary) and 35:1 (upper primary) (Government of India, 2009; Ministry of Education, 2025). Yet this aggregate conceals an acute distribution problem. In 2024–25, the state reported 562 single-teacher schools, 17.4% of all schools, enrolling 6,912 students, and 22.2% of its schools had ten or fewer students, the highest share of micro-schools in the country alongside Ladakh and Uttarakhand; average enrolment per school, at 99, is far below the national average of 168 (Ministry of Education, 2025). The pattern mirrors the national diagnosis that teacher deployment, not teacher supply, is the binding constraint (Mehta, 2025), but in an extreme form produced by settlement geography: very small habitations generate very small schools, which are simultaneously overstaffed in ratio terms and understaffed in absolute terms, since a single teacher cannot offer subject-specialist instruction in science or mathematics regardless of how few pupils sit before them.

Press reporting adds a further, presently unverified, dimension: an estimated 227 trained teachers, including subject teachers of science, mathematics and English, are said to be deployed to administrative desks in the Directorate of School Education and Samagra Shiksha rather than to classrooms (Sangno, 2025). We flag this figure as journalistic and uncorroborated by official data, but note that the underlying practice of scarce subject teachers being moved to non-teaching roles is consistent with the deployment pathology visible in the official statistics.

The state's chosen remedy is consolidation. Around 600 schools with zero or negligible enrolment were closed or merged by mid-2024, and closure of a further 386 zero-enrolment schools was ordered in 2025 (Arunachal24, 2024; Times Now, 2025). The consolidation is visible in the administrative data: the UDISE+ school count for the state fell from 3,490 in 2023–24 to 3,229 in 2024–25 (Ministry of Education, 2024, 2025). Consolidation plausibly enables subject-specialist staffing and justifies infrastructure investment at surviving schools; it equally raises travel and hostel burdens in a state of dispersed settlements, and its net effect on access and learning is an empirical question the state should commit to measuring rather than assuming.

4.4 Data-system reliability

A mission premised on real-time performance tracking presupposes reliable data. Two observations counsel caution. First, the figures presented to the Legislative Assembly (3,496 schools; approximately 272,000 students; 23,224 teachers) differ non-trivially from the UDISE+ 2024–25 figures (3,229 schools; 319,826 students; 25,117 teachers) (Education Times, 2025; Ministry of Education, 2025); whatever the reconciliation, the discrepancy indicates that the state's own information systems are not yet consistent. Second, Aadhaar seeding of student records in the state stood at 74.9% in 2024–25, among the lower rates nationally (Ministry of Education, 2025), which limits the individual-level tracking on which NEP-aligned monitoring is built. Independent audits elsewhere in India have shown official learning data to be substantially inflated relative to independent re-tests (Muralidharan & Singh, 2021); there is no reason to presume Arunachal Pradesh is immune.

5. THE INTERVENTION LANDSCAPE

Against this infrastructural background, a portfolio of STEM interventions operates in the state. They embody markedly different design philosophies, and comparing them is analytically useful precisely because they distribute differently across the layers of the digital divide.

5.1 Connectivity-dependent national models: Atal Tinkering Labs

The Atal Tinkering Lab (ATL) programme of NITI Aayog's Atal Innovation Mission is the central government's flagship vehicle for experiential STEM learning, providing grants-in-aid for school makerspaces equipped with 3D printers, robotics kits, sensors and microcontrollers, with the stated aim of cultivating design thinking and computational skills among students of Grades VI-XII (Atal Innovation Mission, 2025). ATLs have been established in Arunachal Pradesh, including in Tawang and East Siang districts. Nationally, UDISE+ 2024–25 for the first time tabulates tinkering-lab availability by state, reflecting the programme's integration into official monitoring (Ministry of Education, 2025). The model's design assumptions, however, are those of the median Indian school: reliable power for electronic equipment, secure space and connectivity for online

resources and mentorship. In a state where 37.7% of schools lack functional electricity and two-thirds lack internet, a uniform ATL rollout would structurally favour the best-connected schools and thereby widen, not narrow, intra-state inequality, the standard second-order effect predicted by the digital-divide literature (van Dijk, 2006; Warschauer, 2003).

5.2 Human-capital-centred models: IBM STEM for Girls

The IBM STEM for Girls programme, implemented with the Department of School Education since 2022 in partnership with the civil-society organisations Quest Alliance and AMYAA, targets more than 13,500 students in Grades 8-10 across 130 secondary and higher-secondary schools, combining digital fluency and coding with life and career skills, teacher training and the creation of a State Resource Group for sustainability (IBM Newsroom, 2022; The Economic Times, 2022). Two design features distinguish it. It addresses the gendered participation gap in STEM that international evidence documents from early schooling onwards (UNESCO, 2017), and its investments are primarily in people students, teachers, and institutional capacity rather than in equipment, making it comparatively robust to infrastructure failure. Its curriculum can be delivered through varied technological means, which, in divide-framework terms, is an intervention aimed at the skills and usage layers rather than the access layer.

5.3 Infrastructure-lite local models: Digi-Kaksha

The most instructive intervention, because it was designed against the state's own constraints, is the Digi-Kaksha project, launched in remote districts including Tirap and Kurung Kumey (Echo of Arunachal, 2023; India Today, 2023). Its defining choice is offline-first delivery: 4K interactive teaching boards pre-loaded with learning content, usable irrespective of connectivity, embedded in the Building-as-Learning-Aid (BALA) approach in which the school's physical environment is itself treated as a pedagogical resource, and accompanied by teacher training in multimedia methods (India Today, 2023; MyGov India, 2024). Digi-Kaksha is thus a comprehensive reform package rather than a hardware drop, and its design directly answers the failure mode documented in hardware-only programmes (Cristia et al., 2017). Whether it improves measured learning has, to our knowledge, not been independently evaluated an evaluation gap we return to in Section 7 but as a design template it demonstrates that digital pedagogy need not wait for universal connectivity.

5.4 Talent-pipeline measures: merit scholarships

At the opposite end of the pipeline, the Arunachal Pradesh Scholarship for Academic Excellence, launched in the 2024–25 'Year of Youth', funds meritorious Arunachal Pradesh Scheduled Tribe students to pursue degrees at the world's top 150 universities by QS ranking, with an explicit preference for STEM fields (Directorate of Higher and Technical Education, 2024). An early version of the notification listed 'Management' rather than 'Mathematics' within the STEM acronym; on enquiry, the office of the Education Commissioner confirmed this to be a clerical error, the intended scope being the conventional STEM disciplines, and reported that three students were availing the scholarship as of 2025 (personal communication, 24 July 2025). The episode is minor but symptomatic: in a system without institutionalised domain expertise at the policy desk, even the definition of STEM can wobble in official documents.

5.5 Community and institutional enrichment: mathematics camps

A series of mathematics enrichment programmes, supported by the Homi Bhabha Centre for Science Education (HBCSE) and the National Board for Higher Mathematics (NBHM), has operated across the North-east. Arunachal Pradesh hosted its first Mathematics Exposure Camp for school students at Roing in December 2024, organised jointly by Jawaharlal Nehru College, Pasighat, and the All Idu Mishmi Students' Union, with resource persons drawn from NBHM, NERIST and colleges across the region (Echo of Arunachal, 2024). The camp model is notable for its partnership structure - a student union as co-organiser illustrates how community bodies can carry educational programming in areas where the state's reach is thin - and for its scalability.

This model has since been consolidated. Under Phase III of the NBHM North-east Programmes (FY 2026–27), a 5-day residential Mathematical Thinking Camp titled 'From Logic to Olympiad to AI' was held at the Jawaharlal Nehru College, Pasighat campus from 29 September to 3 October 2026 for 55 students of Classes VIII–X, selected on

merit with a school-diversity cap per institution. The camp was sponsored by HBCSE, TIFR Mumbai, supported by NBHM and hosted under the DBT Star College Programme, in collaboration with Arunachal Pradesh University (Pasighat) and Dera Natung Government College (Itanagar). Resource persons were drawn from the Assam Academy of Mathematics, HBCSE Olympiad training faculty, NERIST, and NIELIT, so that the five days bridged elementary logic, Olympiad-style problem solving, and an introductory exposure to artificial intelligence as a mathematical practice (Arunachal Times, 2026).

For the argument of this review, two features of the Pasighat camp are analytically important. First, the camp operated entirely at the human layer of the educational ecosystem residential mentoring, problem-solving sessions, and interaction between school students and research mathematicians and was therefore essentially connectivity-independent. It thus illustrates that serious enrichment in a state at the low end of UDISE+ digital-readiness indicators does not require waiting for universal connectivity. Second, the camp was delivered through an inter-institutional partnership spanning a central scientific institution (HBCSE/TIFR), a national funding body (NBHM), and three state colleges, demonstrating that the thin state administrative apparatus can be effectively leveraged when scientific institutions outside the state supply pedagogical content and local colleges supply hosting capacity. Together with the Roing 2024 camp, the 2026 Pasighat camp indicates that a scalable, pedagogy-first enrichment track exists in the state's own portfolio, one whose principal binding constraint is sustained funding and faculty time, not devices or bandwidth.

5.6 A strategic juncture

Read together, the portfolio reveals a strategic choice. The nationally standardised, connectivity-dependent model (ATL) and the locally adapted, offline-first model (Digi-Kaksha) rest on incompatible assumptions about infrastructure, while the human-capital models (IBM STEM for Girls, exposure and thinking camps) are largely orthogonal to both. Nothing in current policy documents indicates that the state has made this choice deliberately; the risk is a default drift towards the nationally visible model because its targets are easiest to count. The analysis of Section 4 implies the opposite ordering: in the medium term the binding constraints are electricity, connectivity and above all teacher capability, so interventions robust to the first two and investing in the third dominate on expected learning per rupee.

6. GROUND-LEVEL EVIDENCE: TWO FIELD STUDIES

6.1 Situated numeracy in the Pasighat markets

The first field study (Panggam, 2025) set out to document the mathematics actually used by 50 vendors in the markets of Pasighat. Its methodological trajectory is itself informative. Vendors initially refused engagement with a written questionnaire, suspecting an official investigation; the student researcher adapted by abandoning the instrument in favour of informal conversation, typically initiated by making a small purchase to establish rapport, after which respondents spoke freely. The adaptation echoes a standard lesson of field research in low-trust settings - instruments carry social meaning independent of their content - and the study's findings should be read as qualitative observation systematised, not as psychometric measurement.

Three findings stand out. First, formal education was a poor predictor of practical arithmetic. Vendors with little or no schooling, particularly vegetable and meat sellers, performed rapid and accurate mental calculations of prices, change, and absolute profit, frequently outperforming more schooled vendors who reached for calculators. Second, competence was format-bound. Asked about percentage profit margins, respondents were dismissive or confused - one replied, in Hindi, 'What do I know of percentage profit; I just take the money I get,' yet the same respondents instantly and correctly answered the concretely framed equivalent ('If you sell for Rs 120 what you bought for Rs 100, what is your gain?'). The difficulty lay in the abstract register of school mathematics, not in the underlying operation. Third, the vendors' fluency was attributed by respondents themselves to daily transactional practice: repeated, consequential, real-world problem solving.

Each of these findings replicates, at small scale and in a new cultural setting, the classic street-mathematics results from Brazil (Carraher et al., 1985; Nunes et al., 1993) and the recent large-sample Indian evidence (Banerjee et al., 2025). The replication matters for local policy in two directions.

Positively, it demonstrates that the communities of Arunachal Pradesh already possess rich informal mathematical practice on which contextualised instruction can build - the resource that ethnomathematics urges schools to recognise (D'Ambrosio, 1985). Cautionarily, the national evidence shows that intuitive competence does not spontaneously convert into formal competence any more than the reverse (Banerjee et al., 2025; Dillon et al., 2017); romanticising market mathematics would be as much an error as ignoring it. The defensible inference is the one drawn in Section 2.3: curriculum and teacher preparation must explicitly construct the bridge between concrete and abstract registers, using locally meaningful contexts - trade, agriculture, construction, weaving - as the concrete anchor. That is a far more specific demand on the SCERT and on textbook adaptation than the general invocation of 'experiential learning'.

6.2 Student perspectives on AI-assisted instruction

The second study (Podo, 2025) examined how students themselves regard the technology-intensive future that policy envisages for them. Classroom observation confirmed the expected baseline: instruction remains dominated by chalkboard delivery of the prescribed NCERT syllabus, with personal devices prohibited during school hours. Awareness of AI was thin and stratified: upper-primary students could gloss the term only as 'a robot' or 'a machine', while senior students knew AI mainly through ChatGPT and were unaware of other tools - though, once the technology was explained, curiosity across ages was strong.

Table 3. Student preferences among teaching methodologies, by class.

Class	Traditional (%)	AI-driven (%)	Hybrid (%)
V	100	0	0
VI	80	0	10
VII	77	3	20
VIII	50	30	30
IX	45	5	40
XII	50	20	30

Note. Adapted from Podo (2025). Percentages are as reported in the source; rows may not sum to 100 owing to non-response and rounding, and the sample within each class is small. Figures should be read as indicating an ordinal age gradient, not precise population shares.

Table 3 summarises the structured preference item. Despite the noted limitations of the data, the gradient is unambiguous: younger children overwhelmingly prefer human instruction, and openness to AI-assisted or hybrid modes rises with age without ever displacing the teacher. The qualitative material explains the pattern. Younger students emphasised comprehension and emotional support; one stated simply that he only understands 'when a real person teaches ', while senior students, more fluent with the technology, articulated its limits with striking precision. In open discussion, a proposal that traditional teaching was outdated was met by the counter-argument that a full shift to AI would exclude families who cannot afford devices, 'especially in North East India, where many people are below the poverty line', a position the group largely endorsed (Podo, 2025). The students' consensus recommendation was a hybrid model in which technology supports rather than replaces the teacher.

Two aspects of this finding merit emphasis. First, the intended beneficiaries of technology-led reform independently reproduce the central conclusion of the experimental EdTech literature - technology as complement, teacher as anchor (Cristia et al., 2017; Escueta et al., 2020; Muralidharan et al., 2019) - and do so partly on equity grounds drawn from lived experience of the divide's household layer. Second, the finding relocates the priority investment: if students will accept technology only insofar as it empowers teachers, then the mission pillar most consequential for the reception of every other pillar is teacher capacity building, and the relevant standard is well-documented professional development that is sustained, content-focused, collaborative and coached, rather than one-off operational training on new hardware (Darling-Hammond et al., 2017).

6.3 Methodological postscript: students as field researchers

Beyond their findings, the two studies illustrate a low-cost pedagogical instrument available to every college in the state: supervised, community-facing undergraduate research. The vendor study required its author to redesign an instrument in the field; the school study required negotiating access and moderating group discussion. These are precisely the inquiry skills that NEP 2020 nominates as goals,

exercised on problems of immediate local relevance, at negligible marginal cost. Embedding such projects in the undergraduate curriculum as the cohort project reported here simultaneously generates local evidence that the state's data systems do not capture and gives students an experiential education in STEM practice itself.

7. CRITICAL DISCUSSION, RESEARCH GAPS AND DESIGN PRINCIPLES

7.1 A three-fold gap

The evidence assembled above identifies three distinct gaps between the state's policy ambition and its present reality. The first is *infrastructural*: on every digital-readiness indicator the state trails national averages by twenty to thirty percentage points, and the mission's connectivity targets require improbable rates of progress in the hardest terrain (Table 1). The second is *organisational*: an apparently comfortable teacher stock is distributed into hundreds of single-teacher micro-schools and, by press account, partially diverted to administrative desks, so that subject-specialist STEM instruction is unavailable precisely where retention already collapses (Table 2). The third is *pedagogical*: classroom mathematics remains abstract and delivery-oriented, while robust mathematical practice flourishes untapped in the surrounding economy, and the bidirectional non-transfer documented nationally (Banerjee et al., 2025) implies that neither side of this divide will convert into the other without deliberate instructional design.

The layered-divide framework orders these gaps for policy. Building connectivity addresses layer one; subsidising household access addresses layer two; but the decisive layers skills and meaningful usage (Hargittai, 2002; van Dijk, 2006; Warschauer, 2003) are addressed only by investment in teachers and curriculum. A mission whose verifiable targets sit almost entirely in layer one is measuring the wrong margin.

7.2 Design principles: an infrastructure-lite synthesis (LITE)

A locally proposed heuristic, the LITE framework - Localised content, Infrastructure-lite tools, Teacher support and Engagement monitoring - derived from feasibility research on e-learning in the state's government colleges (Jamoh, 2025), maps almost exactly onto the international evidence reviewed here, and the state's own Digi-Kaksha project and the Pasighat Mathematical Thinking Camp already demonstrate its feasibility at school and camp level, respectively. We consolidate the synthesis into four recommendations, each tied to the evidence that motivates it and to an indicator by which its implementation could be judged.

First, adopt a pedagogy-first, technology-second sequencing. Technology procurement should follow, not precede, the specification of the instructional practices it is to support, given the consistent evidence that hardware without pedagogy yields nothing (Cristia et al., 2017) while pedagogy-integrated and level-adaptive uses yield much (Banerjee et al., 2017; Muralidharan et al., 2019). *Indicator:* the share of mission expenditure on teacher development and curriculum relative to hardware.

Second, deploy an 'ATL-lite' variant for widespread rollout. The tinkering-lab objective of designing through making can be pursued with durable, offline-capable equipment (single-board computers with pre-loaded software, mechanical and electronics toolkits) on the Digi-Kaksha pattern, reserving the full connectivity-dependent ATL configuration for schools that can sustain it. *Indicator:* the distribution of functioning labs across connectivity strata of schools, not the aggregate count.

Third, invest in contextualised, sustained teacher professional development. Training should equip teachers to design instruction that bridges the concrete-abstract divide documented in Section 6.1, using local economic and ecological contexts, and should follow the documented features of effective professional development duration, subject focus, collaboration and coaching (Darling-Hammond et al., 2017) rather than one-off device orientation. *Indicator:* hours of subject-focused, classroom-embedded training per teacher per year, and independently assessed change in classroom practice.

Fourth, institutionalise domain expertise and localised curriculum development. A dedicated STEM cell within the SCERT, staffed or advised by subject specialists drawn from the state's higher-education institutions and from scientific institutions outside the state (HBCSE, NBHM, NERIST), should lead the development of curriculum modules that teach universal scientific and mathematical

principles through Arunachali contexts, and should commission independent evaluation of the state's flagship interventions beginning with Digi-Kaksha, for which no learning-outcome evaluation is yet public. The scholarship-notification episode of Section 5.4 illustrates, in miniature, the cost of policy machinery that lacks routine access to domain expertise. *Indicator:* publication of independent evaluations and of locally developed modules in use.

7.3 Research gaps and future directions

The review identifies four research gaps that deserve concerted attention. First, the state lacks any publicly available learning-outcome evaluation of its flagship interventions, including Digi-Kaksha; even a modest quasi-experimental design comparing matched schools would be valuable. Second, teacher-deployment data have no publicly linked dimension to subject qualification, so the actual availability of subject-specialist STEM instruction at school level cannot presently be estimated; a one-time audit linking UDISE+ with teacher-subject records would close this gap. Third, the longitudinal effect of school consolidation on access, retention, and learning has not been documented, although it is the mission's largest ongoing structural change. Fourth, the replication reported here of the Banerjee et al. (2025) bidirectional non-transfer in a tribal North-eastern context should be examined with a properly powered design across multiple districts and languages, as the current literature on street mathematics is overwhelmingly drawn from urban and semi-urban samples.

7.4 Measuring what matters

Finally, the mission's own success criteria should be re-weighted towards outcomes. Administrative completion is a treacherous proxy for educational change (Muralidharan & Singh, 2021). Periodic, independently administered learning assessments on the ASER pattern (ASER Centre, 2025), at state and district level, would give Mission Shikshit Arunachal the one indicator its stated purpose actually requires: whether children in Arunachal Pradesh are learning more mathematics and science than they were when the mission began.

8. LIMITATIONS

This review has clear limitations. The two field studies are small, non-random, and confined largely to one district; their findings are used as structured local observations validated by convergence with larger literatures, not as estimates for the state. Several system-level claims rest on press reporting and are flagged as such; at least one, the redeployment of 227 teachers to administrative roles, remains unverified against official records. Administrative statistics carry their own caveats: UDISE+ warns against comparison across its methodological break; state-reported and UDISE+ figures disagree, and Aadhaar seeding gaps limit individual-level inference. The policy environment is moving quickly; Mission Shikshit Arunachal is in early implementation, and infrastructure programmes announced in 2025–26 will take time to register in the data, so the quantitative picture reported here reflects sources available to mid-2026 and should be re-examined as new UDISE+ rounds and any mission progress reports appear. Finally, this article makes no causal claims; its contribution is diagnostic and design-oriented.

9. CONCLUSION

Arunachal Pradesh has committed itself, on paper, to one of the more ambitious state-level educational transformations in India. This analysis finds the commitment genuine but the theory of change incomplete. The state's binding constraints are not primarily the ones its measurable targets address: they are the distribution of its teachers, the capability of its classrooms and the untraversed distance between the abstract mathematics of the syllabus and the concrete mathematics of its markets and villages. The interventions already present in the state contain, between them, the elements of a workable model: the offline-first design of Digi-Kaksha, the human-capital focus of the girls' STEM programme, and the community partnerships of the Roing 2024 Mathematics Exposure Camp and the Pasighat 2026 Mathematical Thinking Camp, and the state's students, when asked, specify the correct architecture themselves: technology in support of teachers, not in place of them.

The evidence reviewed here converges on a modest but demanding prescription. Sequence pedagogy before hardware; adapt national programmes to local infrastructure rather than the reverse; invest most heavily in sustained, subject-focused teacher development; build curriculum bridges between situated and formal mathematics; and measure success by independently assessed learning, not by

installed equipment. None of this requires resources beyond those the state has already pledged. It requires, rather, that the mission's considerable political energy be pointed at the layers of the problem where learning is actually produced. If that redirection occurs, Arunachal Pradesh's combination of small system size, strong community institutions and demonstrated local innovation could make it not a laggard adapting national templates, but a reference case for STEM education reform in low-density, low-connectivity regions within India and beyond.

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Ethics approval and informed consent. The two field studies synthesised in Section 6 were undergraduate dissertations conducted under faculty supervision at Jawaharlal Nehru College, Pasighat. Verbal informed consent was obtained from all participants prior to the interview, and no personally identifying information is reported. The studies were reviewed and approved by the Department of Mathematics as part of the B.Sc. dissertation requirement. No animal subjects were involved.

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Data availability. The administrative data analysed are publicly available from the UDISE+ portal of the Ministry of Education, Government of India (), and from the ASER Centre (). The two undergraduate dissertations synthesised in this article are openly archived on Zenodo (Panggam, 2025, ; Podo, 2025,).

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