CHAPTER 15

INTELLIGENT TUTORING SYSTEMS FOR ENHANCING ACADEMIC PERFORMANCE OF SECONDARY STUDENTS IN INDIA

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Abstract

Background: *The secondary education system in India is opening access and digital infrastructure, but a significant portion of classrooms have large within-grade learning dispersion, which limits teacher-centered instruction and leads to poor academic performance.*

Objective: *In order to synthesize evidence on Intelligent Tutoring Systems (ITS) and PAL to enhance academic performance in secondary-stage students in India, a combination of national official data and a multiple-case case study of published PAL/ITS applications.*

Methods: *Explanatory multiple-case design that is desk-based and has embedded units (school contexts). The researcher triangulated: (i) national statistics and assessments (UDISE+, ASER 2024, National Council of Educational Research and Training large-scale assessment systems); (ii) peer-reviewed and working-paper RCTs evidence of PAL/ITS; (iii) program documentation and registry data. The researcher took out sample characteristics, measures, outcome measures (standardized test scores, exam results, use), and implementation processes and proceeded to within- and cross-case synthesis, taking into account measurement alignment and scalability threats.*

Results: *In 2024-25, national indicators provide secondary GER 68.5% and secondary dropout 8.2%; schools with computer and internet access were 64.7% and 63.5% respectively. Evidence of the cases shows that large learning gains can be obtained on independent tests (math: 0.22-0.43 SD at scale; 0.37 SD in an efficacy trial) and grade level school tests might fail to reflect such gains when instruction aims several years below grade norms.*

Conclusions: *ITS/PAL is capable of significantly enhancing learning among post-primary students in India under realistic conditions of the public-system, but the improvement in performance requires dosage, device access, teacher integration, governance and redesigning of assessment. Existing ICT funding under Samagra Shiksha must be the policy pathways, in line with NDEAR interoperability, and meet child-data protection requirements in the then-developing data protection laws.*

Keywords: *Intelligent Tutoring Systems; Personalized Adaptive Learning; Learning Outcomes; Randomized Controlled Trial; Digital Infrastructure.*

Introduction

Context and problem statement: In India, secondary education is at a crossroads: Grade 9-10 of every school is a turning point of leaving and a determining factor of further labour-market and higher-education life course. Most of the recent national school statistics (reported as key findings of UDISE+ 202425) demonstrate positive change in access and retention indicators-secondary GER increasing to 68.5% in 202425 (66.5 in 202324), and secondary dropout decreasing to 8.2 (10.9 in 202324). As shown by large-scale survey learning, however, and experimental results, in post-primary grades, a significant fraction of students are several years below the norms of the curriculum, suggesting that coverage of syllabus can not necessarily mean that students have mastered the pre-requisite skills, particularly in mathematics and language. [2,11] [19]

Why ITS now? ITS/PAL is especially timely in India in 2026, as there are two conditions. To begin with, digital accessibility among schools is on the rise: the number of schools that report having access to computers has expanded to 64.7% and access to internet to 63.5% in 202425 (compared to 57.3% and 53.6% in 202325). Second, the national digital educational ecosystem is converging to interoperable platforms and reusable building blocks (e.g., NDEAR; DIKSHA), allowing assessment services, identity services, content services, analytics services, etc., to be similarly modularly integrated. [20]

Research aim and questions: This research article asks:

1) What is the evidence that ITS/PAL improves academic performance for secondary-stage learners in India, and how do effect sizes vary by delivery model (after-school vs in-school; laptops vs tablets)?
2) Which implementation mechanisms (dosage, teacher role, monitoring, device access) appear most influential for learning gains at scale?
3) What policy design features—financing, interoperability, assessment alignment, and data governance—are required for durable gains in India's public secondary education system?

Assumptions and scope: Since no particular state/region/site was given, the researcher (i) considers this to be a national-level synthesis using official, all-India indicators; and (ii) uses two exemplary school-level cases using documented pilots an urban after-school model (Delhi catchment) and a rural-heavy in-school model (Rajasthan Adarsh schools) supplemented with a government-led scale model (Andh These include mostly Classes 6 9; we explain our relevance to secondary education by (a) Class 9 is in secondary and (b) the accumulated deficit of skills in Class 8 9 has a material effect on secondary academic achievement and readiness to pass board exams.

Literature review and theoretical framework

Definition and architecture of ITS: ITS are computer-based teaching systems that change content, feedback, and sequence of problems based on the changing knowledge state of a particular learner. In the majority of traditional formulations, an ITS consists of: a domain model (skills/knowledge components), a student model (probabilistic estimate of mastery), a pedagogical/tutor model (rules to give hints, remediation and sequencing), and a user interface. One of the earliest methods is the knowledge tracing - probabilistic updating of mastery beliefs in the attempt of a learner to solve items, first mathematically modeled by Albert T. Corbett and John R. Anderson in Bayesian form. [18]

Effectiveness evidence: what the global literature says? Meta-analytic research in educational psychology shows that ITS tend to be effective, although the sizes of effects differ depending on outcome measure, comparison condition and context. Wenting Ma and colleagues combined 107 effect sizes (14,321 participants) and found positive effects in education levels and areas. According to James A. Kulik and J. D. Fletcher, a median effect of about 0.66 SD was observed in 50 controlled ITS assessments, and they point out that measured gains were strongly dependent on the fit between assessment and instructional objectives- a problem that lies at the heart of the Indian scale cases discussed here. Kurt VanLehn also defines families of design based on the interaction granularity (answer-based and step-based), claiming that human tutoring is sometimes as effective as computer tutoring when it comes to certain conditions. [16]

Why India is a high-variance setting for ITS: The focal pedagogical limitation in most Indian classrooms is not just time scarcity, but extreme within grade heterogeneousness of learning levels. In the assessment of Adarsh schools in Rajasthan, before the introduction of Mindspark instruction, the average performance of Grade 8 students in math was about Grade 4, with students of various grades of achievement in one classroom. As a result of this heterogeneity, the efficacy of one-pace instruction is diminished and focused remediation is a realistic high-leverage intervention.

Theoretical framework: mastery learning and teaching at the right level: The mastery learning and curricular-right-sizing are integrated in the theoretical lens. Mastery learning, popularised by Benjamin S. Bloom[36], argues that the majority of learners can attain high levels of mastery with adequate time, good feedback and corrective instructions that is, the processes of diagnostics and personalization are not peripheral tools. PAL/ITS puts this mechanism into practice: they are diagnosing followed by providing customized practice with instant feedback. The India PAL evidence base is consistent with this theory: massive gains are seen in independent adaptive tests despite small change seen in grade-level tests, which are in line with learning recovery on below-grade baselines.

Policy and system alignment: The policy architecture in India also favors the fairness of technology and digital ecosystem construction. NEP 2020 contains a specific concern of technology use and online/digital education in order to assist fair learning. NEP 2020 goals, such as breaking the overemphasizing on memorization and shifting to competency development, the orientation that adaptive diagnostics and practice is compatible with, are operationalized by the National Curriculum Framework (NCF) of school education ([6]]. ICT funding and digital targets under the samagra Shiksha expressly facilitate the Government and aided schools; in Classes VI through to Class X; this provides a financing mechanism through which ITS/PAL labs can be funded. [4] Interoperability aspirations in NDEAR also mean that ITS/PAL must be viewed as being modular services that are combined with national platforms and not pilots. [5]

Methodology

Design: The study design implemented by the researcher was an explanatory and embedded multiple-case study (desk-based) which is appropriate in situations where (i) causal findings are obtained by the rigorous quantitative appraisal, but (ii) the uptake of the policy would require insights into the implementation processes and contextual contingencies. The cases were chosen to differ on: the delivery model (after-school vs in-school), technology substrate (computer lab vs tablets), and the governance model (NGO supported vs state-run).

Case sampling and units of analysis: Purposeful sampling (maximum variation) yielded three evidence-rich cases:

- **Case A (Urban efficacy):** Delhi after-school PAL/ITS program (Mindspark) was the strategy tested through a scholarship/lottery allocation system among learners in Grades 69 among public middle schools. [10]
- **Case B (Scale adaptation):** The Rajasthan in-school Mindspark program was part of the Programs in the schedules of "Adarsh" integrated public schools (Grades 112) in both rural and urban in four districts. [11]

- **Case C (Government-led PAL labs):** Andhra Pradesh PAL implementation with Grades 6-9 students through 1-to-1 implementation of tablets in special purpose PAL laboratories over a period of approximately 17 months (120 schools (60 treatment/60 control) in a randomized design).

Embedded units were "school implementation contexts" (urban sample, rural-heavy sample, and statewide government lab model). In cases where school-specifics were not publicly listed, we documented only features that were available and made clear what had been assumed in operation (e.g. timetabling norms), without fabricating it.

Data sources: The researcher triangulated four source classes:

1) **Official national statistics and infrastructure indicators** from UDISE+ 2024–25 key findings. [1] [2]
2) **Learning and enrolment benchmarks** from Annual Status of Education Report 2024[46] (ASER 2024). [2]
3) **National assessment system documentation** from NCERT/PARAKH resources (NAS 2021 page; PRS 2024 national report).
4) **Peer-reviewed** RCT results (Delhi Mindspark), working-paper scale evidence (Rajasthan Mindspark), program evaluation summary Andhra Pradesh, registration documentation (AEA RCT registry).

Instruments and extraction protocol: The researcher applied a structured evidence extraction template that included: (i) sample frame; (ii) randomization unit and timeline; (iii) measurement instruments (independent assessments vs school exams; item ranges; standardization method); (iv) implementation model (hardware, staffing, teacher role, monitoring); and (v) outcomes (effect sizes, usage, subgroup heterogeneity, exam impacts, cost parameters). Threats to scale (dose reduction, displacement of instructional time, teacher adaptation) were also extracted by the researcher.

Analysis strategy: The within-case synthesis generated logic models between implementation features and learning outcomes; the cross-case synthesis compared the effect sizes and mechanisms. The researcher report standardized treatment effects (SD units) as the key similar measure, noting that tests in different cases are not identical; therefore, cross-case comparisons are interpretive, but not mechanistically the same (assumption mentioned). The researcher also report conversions of equivalent years of schooling used by authors of studies where it is available. [17]

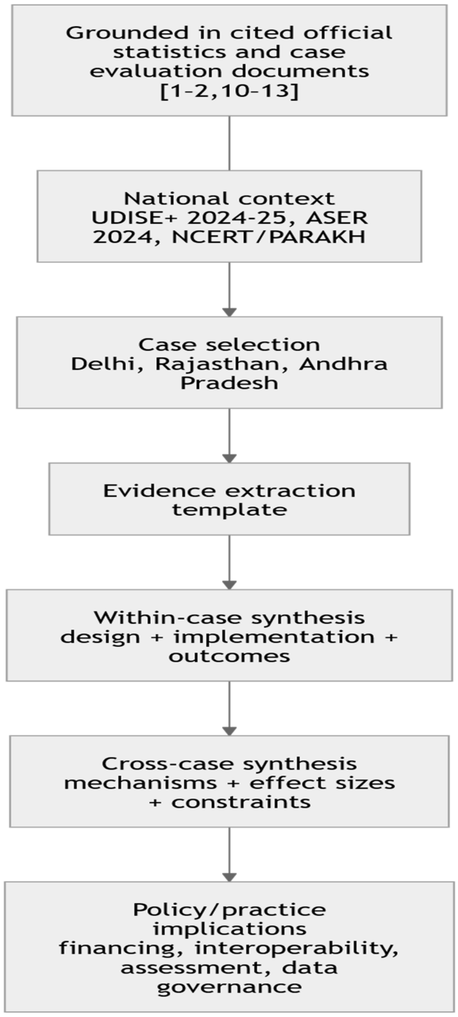

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Figure 1

Results

National context: access, retention, and digital readiness: Table 1 contains a summary of the latest reported all-India indicators applicable to ITS feasibility and secondary performance constraints. Secondary GER is still below 70, and secondary retention is still low compared to the previous levels, which means that academic support in Classes 8-10 can be consequential to performance and persistence. The digital infrastructure has been enhanced at a high pace implying that the properly designed ITS/PAL models can be provided by the available ICT labs or tablet labs, yet, a nontrivial connectivity gap remains. [13]

Table 1. Selected national indicators relevant to secondary ITS/PAL deployment (All-India)

Indicator (All-India)	2023–24	2024–25	Interpretation for ITS/PAL	Source
Secondary GER (%)	66.5	68.5	Expanding target cohort; still substantial unmet enrolment at secondary level	[1], [2]
Secondary dropout rate (%)	10.9	8.2	Improved retention; remediation may further reduce attrition	[1], [2]
Middle→Secondary transition rate (%)	83.3	86.6	Transition improving; bridging learning gaps at Class 8–9 remains critical	[1], [2]
Schools with computer access (%)	57.2	64.7	ICT labs expanding; supports lab-based ITS where available	[1], [2]
Schools with internet facility (%)	53.9	63.5	Connectivity improving; offline-capable ITS still needed for residual gaps	[1], [2]
Out-of-school (age 15–16) (%)	—	7.9 (2024)	Even among older adolescents, non-enrolment persists; targeted support may aid re-engagement	[2]

Policy timeline and enabling ecosystem: Figure 2 situates ITS/PAL feasibility in the policy and infrastructure journey of India: digital ecosystem blueprinting (NDEAR), national teacher/student platform (DIKSHA) and financing norms of ICT labs in Samagra Shiksha provide a viable system pathway between pilots and scale, in case learning measures and data management are standardized.

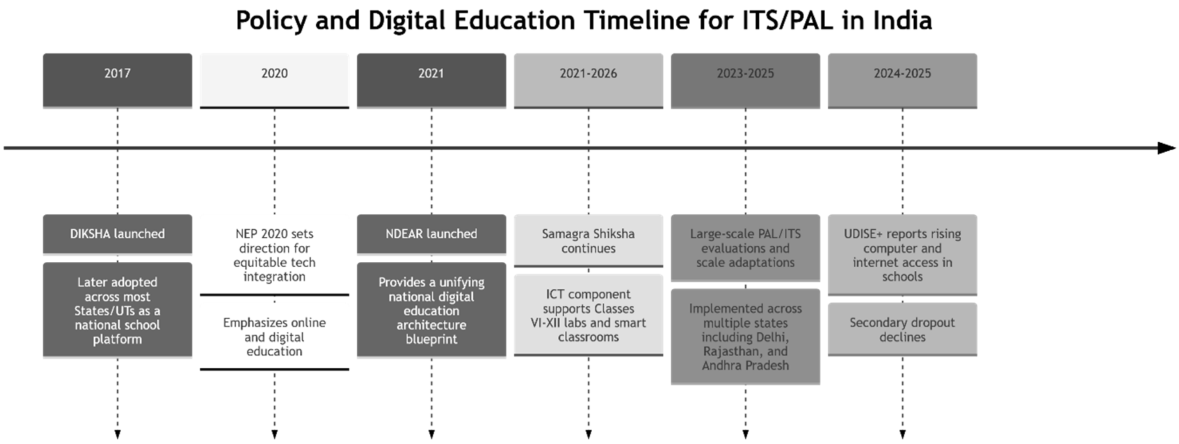

Figure 2

Platform comparison: ITS/PAL options and evidence features: Table 2 is a comparison of three prominent systems in the Indian ITS/PAL landscape: Mindspark (computer-adaptive PAL with RCT evidence), CG PAL (tablet-based PAL with a reported randomized evaluation), and DIKSHA (foundational national platform that will allow distribution, but is not an ITS). The main policy implication is that the ecosystem in India most probably needs: (i) an interoperable rail (DIKSHA/NDEAR-aligned services), and (ii) PAL/ITS-based applications (evidence-based) that are interconnected into rails. [3,5]

Table 2. Comparative features of selected platforms relevant to secondary learners in India

Platform	Delivery substrate	Core ITS/PAL functionalities	Evidence base (India)	Notes for secondary performance
Mindspark (by Educational Initiatives)	Computer labs; structured after-school centers	Adaptive diagnostics; individualized sequencing; high-frequency feedback; tracks within-grade dispersion	Delhi lottery-based RCT (Grades 6–9) with large short-run gains; Rajasthan cluster RCT (Grades 5 & 8 in integrated schools) showing gains on independent tests but not on school exams	Strong for remediation and competency building; exam alignment requires bridging content and assessment redesign
CG PAL (by ConveGenius.AI; state-led program)	Tablet labs (30 tablets/school reported)	Adaptive diagnostics and practice; usage dashboards; field support and monitoring	Andhra Pradesh randomized evaluation summary reports 0.43 SD gain in math over ~17 months (Grades 6–9) [12]	Reported gains largest in lower grades and among girls; device access and class-size constraints affect usage [12]
DIKSHA (NCERT/MoE platform)	Web + mobile	Repository, courses, assessments; analytics; multilingual; open-source building blocks (Sunbird)	National platform adoption across most States/UTs; enables teacher/student programs at scale [3]	Not an ITS itself; can serve as distribution + identity + content/assessment rails for ITS/PAL integrations

Case sample characteristics: Table 3 summarizes the design of the cases, samples, and measurements. Two patterns are important in interpreting the effects of academic performance:

(i) in cases where tests are adaptive or measure a broad range of abilities, the measured effects are large; (ii) in cases where the measure of performance is based on grade level school exams, the effects of learning may be insignificant even when learning is higher, because instruction is below grade-level. [17]

Table 3. Case characteristics: setting, sampling, instruments, and outcomes

Case	Setting and delivery model	Sample and grades	Design and instrument(s)	Primary outcomes reported
A: Delhi urban after-school PAL	After-school PAL/ITS centers serving public-school students	Grades 6–9; study focused on middle-school grades; centers catered wider range [10]	Lottery-based access; independent standardized tests in math and Hindi [10]	+0.37 SD math; +0.23 SD Hindi in ~4.5 months (ITT) [10]
B: Rajasthan in-school PAL at scale	In-school labs in Adarsh integrated public schools (Grades 1–12), across rural and urban areas	~80 schools; treated ~40 schools and ~6,500 students annually; key grades analyzed include Grade 5 and Grade 8 [11]	Cluster RCT; independent tests with IRT scaling; school exam outcomes analyzed separately [11]	~+0.22 SD math; ~+0.20 SD Hindi after 18 months; no evidence of improvement on school exams [11]
C: Andhra Pradesh government-run PAL labs	Tablet-based PAL labs; 2×40-minute weekly sessions reported; field + government monitoring	Grades 6–9 across 120 schools in eight districts (60 treatment/60 control) [12]	Randomized control design; tablet-based math assessment spanning Grade 2 to current grade with validated items [12]	+0.43 SD (95% CI 0.29–0.56) ≈ +1.9 equivalent years of schooling over ~17 months; higher gains for girls and lower grades [12]

Learning gains: cross-case visualization: The standardized learning gains in mathematics in the three cases in India are visualized in figure 3 (with an accent on the fact that) (a) large short-run efficacy gains can still decline at scale (usually due to a reduction in dosage), and (b) large impacts can also be achieved with well-manageable scale models.

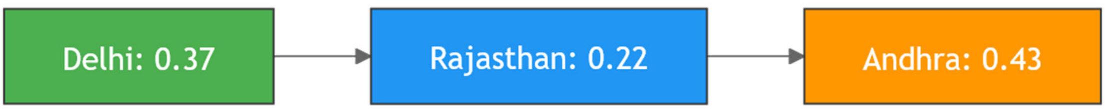

Figure 3

Outcome metrics beyond test scores: exam alignment and productivity: The scale-adapted study of Rajasthan directly notes no evidence of scale effect on school examinations, with statistically insignificant effects and small negative point estimates, attributing this to the fact that instruction was given at the actual learning levels of students (often several years below grade levels), and that grade-level instruction was reduced since PAL had to replace some of the classroom time. This gap of measurement is not a failure of PAL as such; it is an indication that academic performance needs a multiplicity of measures: (i) competency gains on broad-range measures to correct remediation; and (ii) grade-level competence to board-oriented measures.

The program documentation of Andhra Pradesh also places high attention on access and usage: students in smaller classes were found to have increased access and usage of tablets (42.3 vs 30.6 hours), and every hour of additional usage was found to be associated with an increase in the equivalent years of schooling (their conversion). It means that the device-to-student ratios and time-keeping fidelity are not the operational aspects but the causal levers.

Indicative cost parameters: Andhra Pradesh's PAL evaluation summary reports an estimated implementation cost of ₹1,682 (~US$20) per student annually, inclusive of hardware, software, monitoring, and field implementation support. [12] Rajasthan's scale paper reports per-student annual costs in the adapted model in the range of ~₹1,718–₹2,903 across years (assumptions in the study) and contrasts this to a much higher per-student cost in the earlier Delhi efficacy model. [11] These figures should be interpreted as program-accounting estimates rather than nationally standardized costs (assumption: cost comparability varies with procurement norms, amortization, and vendor pricing), but they reinforce the policy logic of integrating PAL into existing ICT assets rather than creating parallel infrastructures. [4]

Discussion and implications for policy and practice

Interpretation: why gains are large yet uneven: The India case evidence is consistent with the mastery-learning hypothesis: when students are far below grade level, individualized diagnosis and practice can generate rapid learning gains. [17] The Rajasthan evidence adds an implementation-science nuance: the same software can deliver smaller average effects at scale when dosage falls, time is displaced, or school routines constrain engagement—yet still produce meaningful gains on independent measures. [11] This is not merely "implementation weakness"; it is an expected systems phenomenon when moving from efficacy to effectiveness conditions.

Mechanism synthesis: what appears to drive impact? Across cases, four mechanisms appear consistently load-bearing:

1) **Diagnosis + adaptive sequencing** addresses within-grade dispersion, a defining feature of post-primary learning gaps in India. [11]

2) **Time-on-task (dosage)** is a primary mediator; Andhra's evidence explicitly links higher usage to larger gains. [12]

3) **Teacher-lab integration matters:** Rajasthan's model expected teachers to accompany students to labs, while local lab-in-charge roles supported maintenance and adherence—illustrating that "human infrastructure" complements algorithmic personalization. [11]

4) **Measurement alignment** determines whether academic gains register in "school performance" metrics; Rajasthan's null effects on school exams likely reflect misalignment between remedial gains and grade-level exam content. [15]

Implications for policy design in India

Financing and procurement: The ICT and Digital Initiatives component of Samagra Shiksha covers Classes VI–XII and provides explicit per-school grants for ICT labs and smart classrooms, including recurring support over five years. This is a direct financing pathway for ITS/PAL integration if procurement frameworks move beyond hardware counts to measured learning gains and uptime/usage KPIs. [4]

Interoperability and platform strategy: NDEAR's ecosystem policy frames education technology as interoperable building blocks delivered via open APIs rather than siloed "end-to-end" systems. ITS/PAL integration should therefore be architected to plug into national rails: identity/rosters, content registries, multilingual support, and analytics dashboards—all areas where DIKSHA and allied services already operate at scale. [20] A policy-relevant model is: DIKSHA/NDEAR for backbone + evidence-backed PAL vendors for tutoring functionality, with standardized data schemas and evaluation metrics.

Assessment reform and accountability: If PAL/ITS primarily remediates below-grade skills, then expecting immediate improvements on grade-level school exams can understate impact and misallocate accountability. Policymakers should adopt dual-metric dashboards: (i) adaptive competency progression (foundational-to-grade-level trajectories), and (ii) grade-level readiness indices aligned with board exam frameworks. Rajasthan's findings demonstrate that without this duality, systems risk interpreting genuine learning gains as "no impact." [15]

Equity and gender: Andhra's reported results show larger gains among girls and younger grades, suggesting that PAL can be an equity amplifier when access and usage are protected. [12] However, equity depends on operational design: device access (class size, device ratio), teacher encouragement, and monitoring. Targeted design for girls' participation and safe lab environments should be built into implementation protocols, especially in settings where adolescent girls face higher out-of-school risks (ASER shows girls' non-enrolment at age 15–16 slightly above boys at all-India rural levels). [2]

Data governance and child safety: ITS/PAL systems process granular student performance data. India's digital regulatory environment—referenced in official government communication—includes the Digital Personal Data Protection Act, 2023, with specific safeguards for children such as verifiable consent and restrictions on tracking/behavioral monitoring and targeted advertising directed at children. [20] Public procurement and school-level deployment protocols should therefore require: data minimization, transparent consent workflows, role-based access, auditability, and strict separation between learning analytics and commercial profiling. The DPDP Rules notification timeline (as summarized in legal analysis) suggests phased compliance horizons; education systems should treat compliance as a design constraint, not an afterthought. [21]

Implications for practice (school leadership and teachers): Effective PAL/ITS use requires structured timetabling, lab management, and teacher engagement. The Andhra case indicates that scheduled periodic usage (two 40-minute weekly sessions) plus school and state-level monitoring can sustain time-on-task. [12] Teacher professional development can be delivered through DIKSHA's large-scale training capabilities and multilingual resources, lowering marginal costs of capacity building. [3] Schools should implement "PAL instruction protocols" specifying: device allocation rules, attendance/usage targets, practice-to-classroom bridging activities, and remediation-to-grade-level transition paths.

Limitations and conclusion

Limitations: This study is a desk-based case synthesis; we did not conduct primary fieldwork (classroom ethnography, direct observations, interviews) and therefore rely on published evaluation documentation and official statistics. The three cases use different tests and scaling conventions; standardized effect sizes improve comparability but do not fully equate constructs (e.g., different item pools, language domains, and stakes). Additionally, much of the strongest India evidence is concentrated in Grades 6–9; while directly relevant to Class 9 (secondary), generalization to Classes 10–12—where curriculum complexity and exam stakes intensify—requires further evaluation. [21] Finally, some recent policy and legal details (e.g., DPDP Rules commencement schedules) are summarized through secondary legal reporting rather than direct gazette text in this article (constraint of accessible primary PDFs in this workflow). [21]

Conclusion: India's secondary education system is increasingly positioned to absorb ITS/PAL interventions because access, ICT infrastructure, and national digital platform architecture are improving. The best available India evidence indicates that PAL/ITS can produce meaningful learning gains for post-primary students—including class 9—especially by remediating foundational gaps that conventional instruction struggles to address in heterogeneous classrooms. [17] For Scopus-indexed-journal-quality policy relevance, the central design implication is not "adopt AI tutors," but "institutionalize evidence-backed personalization within system constraints": finance through existing Samagra ICT norms, integrate through NDEAR/DIKSHA interoperability, measure with dual metrics that reflect both remediation and grade-level readiness, and embed child-data safeguards under India's data protection regime.

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