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ADAPTIVE AI IN THE CLASSROOMS OF KHYBER PAKHTUNKHWA: EVIDENCE, EQUITY AND POLICY

Dr. Bushra Salahuddin[1], Dr. Muhammad Mujtaba Haider[2], Dr. Sultan Akbar Shah[*3]

[1]*Assistant Professor, Institute of Education and Research, Faculty of Arts and Social Sciences, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan.*
[2]*Lecturer, Advanced Education department, Agriculture university Dera Ismail khan*
[*3]*Lecturer, Institute of Education and Research, Faculty of Arts and Social Sciences, Gomal University, Dera Ismail Khan, Khyber Pakhtunkhwa, Pakistan*

[1]bushramuab@gu.edu.pk, [2]mujtabahaider786110@gmail.com, [*3]sultanakbar@gu.edu.pk

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Dr. Sultan Akbar Shah

Abstract
Pakistan has made real progress in getting children into school, yet far too many leave the early grades without mastering basic reading and numeracy. This article examines whether adaptive artificial intelligence (AI) systems, which adjust content, pace and feedback to each learner, can help close that gap in Khyber Pakhtunkhwa (KP). Using a narrative review of meta-analyses, randomised trials and recent educator surveys, we show that the international evidence for adaptive and intelligent tutoring systems is consistently positive, with reported effects ranging from about 0.2 to 0.8 standard deviations, and that the gains are largest for children who start furthest behind. At the same time, we find no large controlled evaluation of such systems in KP itself, and we identify infrastructure, language, gender and algorithmic bias as the conditions that will decide whether adoption helps or harms. We conclude with a four-phase pathway: build foundations, localise and pilot, evaluate independently, and scale only what works.

1.INTRODUCTION
Walk into a government primary classroom in KP and you will often find one teacher, several grades and a chalkboard. The teacher is doing what is humanly possible, yet a single pace of instruction cannot suit thirty or forty children who arrived with very different foundations. Some are bored within minutes; others quietly fall behind and never catch up. What results is a learning crisis rather than a schooling crisis. The World Bank (2023) estimates that roughly 77% of Pakistani ten-year-olds cannot read and understand a simple age-appropriate text (Figure 1), a figure that has barely moved even as enrolment has grown.

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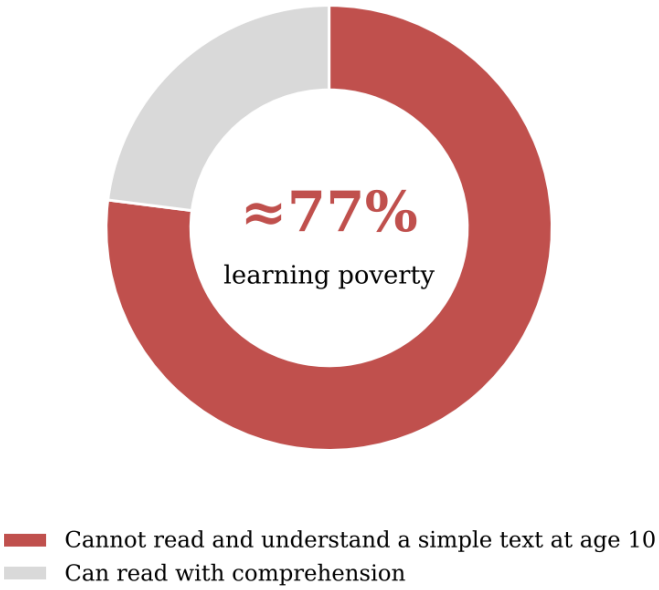

Figure 1. Learning poverty in Pakistan: share of ten-year-olds unable to read and understand a simple text. Data: World Bank (2023).

Adaptive AI offers a tempting response. Such systems observe how a learner answers, adjust the difficulty of the next task, and give immediate feedback, in effect delivering a measure of the individual attention that crowded classrooms cannot. Enthusiasm, however, should not outrun evidence. Technology has disappointed before, and a recent review of experimental studies cautions that results depend heavily on how tools are designed and used (Escueta et al., 2020).

This article therefore asks three questions. First, what does rigorous evidence say about the effectiveness of adaptive and intelligent tutoring systems? Second, what does that evidence imply for KP, given its linguistic, gender and infrastructure realities? Third, what policy sequence is most likely to produce benefit without deepening existing inequalities?

2. REVIEW APPROACH

This is a narrative review, not a systematic meta-analysis. We prioritised peer-reviewed meta-analyses, randomised controlled trials and major institutional reports, because these provide the most reliable estimates of effect. Pakistan-specific evidence is far thinner, so we also drew on a recent educator survey (Raza & Farooq, 2025). Effect sizes are reported as the original authors presented them and are expressed, where possible, in standard-deviation (SD) units. Because the studies differ in subject, age group and design, the figures illustrate the general magnitude of effects and should not be averaged or treated as directly comparable.

3. CONCEPTUAL FOUNDATIONS

3.1 Why personalisation should work

Conventional teaching in large classes follows a single instructional path. Adaptive systems are instead grounded in constructivist and cognitive principles. Vygotsky's (1978) notion of the zone of proximal development captures the central idea: learning is most productive when tasks are pitched just beyond

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what a learner can currently do alone. An adaptive tutor tries to keep each child inside that zone, easing the task when a student struggles and stretching it when the student is ready. A second principle is the spacing of practice. Reviewing material at well-timed intervals strengthens long-term retention (Cepeda et al., 2006), and software can schedule such review for every learner at once, something a teacher can rarely do by hand.

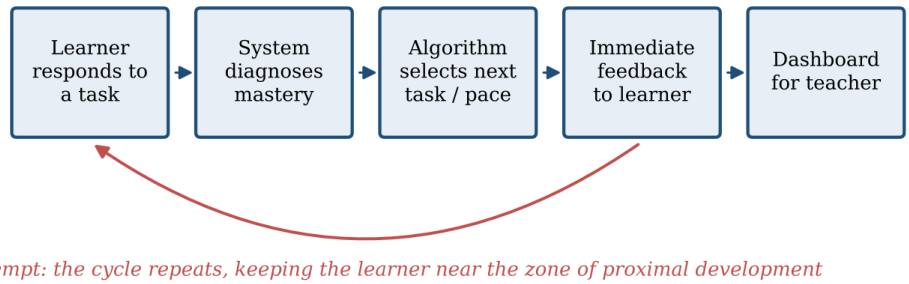

Figure 2. The adaptive learning cycle: each learner response informs the next task, while teachers receive information to guide their own support.

3.2 Traditional versus adaptive instruction

Table 1 contrasts the two models along the dimensions most relevant to KP's classrooms. It is a conceptual comparison drawn from the principles above, not an empirical scoreboard, and it also shows where each model is strong. Adaptive tools are not a substitute for teachers; they relieve the particular constraints of pace, feedback and time that large, multi-grade classes impose.

Table 1. Conceptual comparison of traditional and adaptive instruction

Dimension	Traditional whole-class instruction	Adaptive AI-supported instruction
Pacing	One pace for all learners	Pace adjusts to each learner's demonstrated mastery
Feedback	Delayed (marked work, tests)	Immediate, task-level feedback
Practice	Same exercises for everyone	Exercises selected by current ability; spaced review possible
Teacher information	Mostly from tests and observation	Learner-level dashboards can show where help is needed
Relational and social learning	Strong: discussion, mentoring, role-modelling	Limited; depends on teacher to preserve it
Main prerequisites	Trained teacher, classroom	Devices, power, connectivity, localised content, teacher training

Note. Conceptual synthesis by the authors based on the sources cited in Section 3.1.

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4. WHAT THE EVIDENCE SHOWS

4.1 International evidence

The strongest evidence comes from syntheses of controlled studies. Kulik and Fletcher (2016) reviewed 50 controlled evaluations of intelligent tutoring systems and reported a median effect of 0.66 standard deviations over conventional instruction. Ma et al. (2014) found a smaller but still meaningful advantage of about 0.4 standard deviations compared with large-group teaching. VanLehn (2011) concluded that well-designed intelligent tutoring systems come close to the effectiveness of one-to-one human tutoring, which has long been considered the gold standard. Table 2 and Figure 3 summarise these findings.

Table 2. Selected evidence on adaptive and intelligent tutoring systems

Study	Setting	Design	Principal finding
Kulik & Fletcher (2016)	Mainly K–12 and college; 50 controlled evaluations	Meta-analysis	Median effect of 0.66 SD for intelligent tutoring versus conventional instruction
Ma et al. (2014)	Primary to higher education	Meta-analysis	Moderate advantage ($g \approx 0.4$) over large-group instruction
VanLehn (2011)	Mixed; review of tutoring studies	Comparative review	Intelligent tutoring approached human tutoring ($d \approx 0.76$ vs 0.79)
Muralidharan et al. (2019)	Urban Indian middle schools	Randomised lottery	Gains of about 0.36 SD (mathematics) and 0.22 SD (Hindi) in 4.5 months
Banerjee et al. (2007)	Primary schools, Vadodara, India	Randomised trial	Computer-assisted learning raised mathematics scores
Escueta et al. (2020)	Many settings worldwide	Review of experiments	Computer-assisted learning, especially personalised practice, among the most promising uses of technology

Note. SD = standard deviation. Effect sizes are as reported by the original authors; designs and measures differ.

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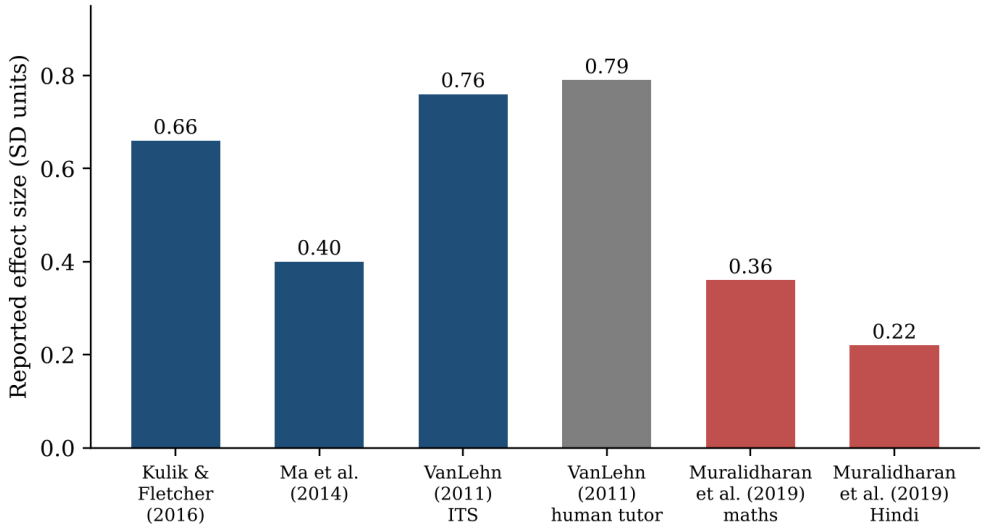

Figure 3. Reported effect sizes from selected studies. Bars are not directly comparable because populations, subjects and measures differ. Sources as in Table 2.

4.2 Evidence from South Asia

Closer to home, Muralidharan et al. (2019) randomly offered urban Indian students access to a personalised, technology-aided after-school programme. After about four and a half months, those offered access gained roughly 0.36 standard deviations in mathematics and 0.22 in Hindi. Weaker students benefited most in relative terms because the software met them at their actual level rather than at the level of the textbook. The programme was also found to be cost-effective. Earlier work reached a similar conclusion: Banerjee et al. (2007) showed that computer-assisted learning produced sizeable mathematics gains for children in Vadodara.

4.3 Why the gains arise

Three mechanisms plausibly explain these results. First, adaptivity reduces mismatch: children spend more time on tasks that are neither trivial nor impossible. Second, rapid feedback allows errors to be corrected before they harden into misconceptions. Third, spaced and varied practice supports retention. None of these mechanisms is mysterious, and none requires replacing the teacher; each is a way of giving more learners more of the attention that good teaching has always provided.

4.4 What is still missing for KP

An honest reading of the literature must also record its limits. To our knowledge, there is not yet a large, independently replicated randomised evaluation of adaptive AI in KP's government schools. Much of what circulates about AI in Pakistani education comes from small surveys and short studies, and a systematic review warns that research on AI in higher education has paid too little attention to pedagogy, ethics and the role of educators (Zawacki-Richter et al., 2019). The Indian results are encouraging and relevant, but KP differs in language, gender norms and infrastructure. They are grounds for well-designed pilots, not for assuming success.

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5. THE KP CONTEXT: READINESS, EQUITY AND CULTURE

5.1 Teacher readiness

A recent survey of 125 Pakistani school educators suggests a workforce that is open to AI but still at an early stage (Raza & Farooq, 2025). More than two-thirds of respondents were willing to adopt AI tools if properly supported, and about one-third already used them frequently. Most use was for lesson planning and content creation, while AI-driven grading and feedback, the very functions that define adaptive learning, were rarely used. Respondents also raised concerns about unequal access and called for more training and infrastructure. Although this sample is not specific to KP, it signals that teacher readiness, not teacher resistance, is the more pressing constraint.

5.2 Infrastructure, language and gender

Three further issues deserve attention. The first is infrastructure: adaptive platforms depend on devices, electricity and reliable connectivity, which are unevenly distributed between urban and rural districts. The second is language. Most commercial tools are built around English and, to a lesser extent, Urdu; children who speak Pashto or Hindko at home risk being served content that is linguistically and culturally distant from their lives. The third is gender. Because girls in KP face greater barriers to staying in school, a technology deployed without attention to their circumstances may widen the gap it was meant to narrow. Programme design should therefore consider safe, supervised access for girls from the outset.

6. RISKS AND SAFEGUARDS

Algorithms learn from data, and data carry the assumptions of those who produced them. Baker and Hawn (2022) document how educational algorithms can perform unevenly across learner groups, systematically disadvantaging some students. A tool trained largely on Western learners may misread local idioms or reflect values that sit uneasily with Pakistani classrooms. Adaptive systems also generate sensitive records, including performance patterns and behavioural traces, which require clear rules on consent, storage and use; UNESCO (2023) offers a useful starting framework for such governance. Finally, if access is concentrated among connected and better-off families, AI could amplify existing inequalities rather than reduce them (Escueta et al., 2020). Table 3 links each risk to a practical safeguard.

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Table 3. Principal risks of adaptive AI in KP and proposed safeguards

Risk	Why it matters in KP	Proposed safeguard
Algorithmic bias	Tools trained on other populations may misjudge local language and culture (Baker & Hawn, 2022)	Pre-deployment bias audits; local validation; teacher override of system decisions
Language exclusion	Pashto and Hindko speakers may receive unfamiliar content	Localised content in Pashto, Hindko and Urdu, reviewed by community educators
Digital divide	Rural and low-income learners may lack devices and connectivity (Escueta et al., 2020)	Start in under-served schools; shared school devices; offline-capable tools

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Risk	Why it matters in KP	Proposed safeguard
Gender gap	Girls face greater barriers to continued schooling	Safe, supervised access; monitor outcomes by gender
Data privacy	Learner records are sensitive (UNESCO, 2023)	Data-protection rules, minimal data collection, clear consent
Over-reliance	Tools may crowd out teacher–student interaction (Zawacki-Richter et al., 2019)	Position AI as teacher support; train teachers in critical AI literacy

Note. Safeguards are the authors' recommendations drawn from the cited sources.

7. POLICY PATHWAY

Taken together, the evidence points to a staged, learning-oriented approach for the Elementary and Secondary Education Department and its partners (Figure 4). The sequence matters: attempting to scale before foundations and evaluation are in place is the surest way to waste resources and erode trust.

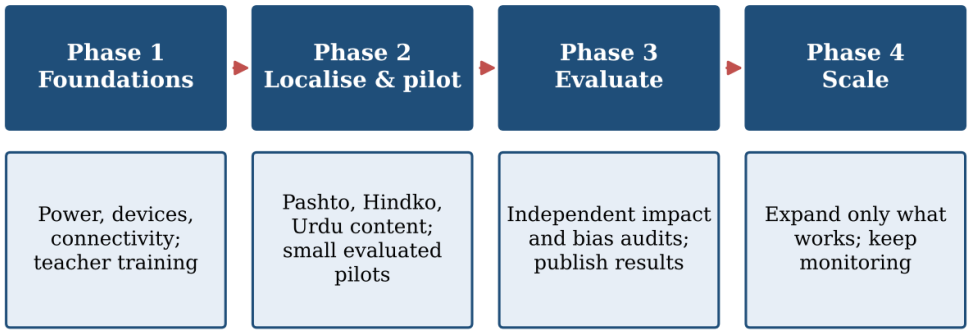

Figure 4. Proposed four-phase pathway for adopting adaptive AI in KP schools.

1. **Build the foundations first.** Prioritise electricity, devices and connectivity in the most under-served districts, and consider public–private partnerships for financing and maintenance.
2. **Invest in teachers.** Offer sustained training that covers not only how to operate tools but also how to judge their outputs, recognise bias and integrate them with classroom teaching. Teachers should be partners in design, not passive users.
3. **Localise deliberately.** Develop or adapt content in Pashto, Hindko and Urdu, and review it for cultural and gender appropriateness with local communities.
4. **Pilot, measure, then scale.** Begin with small, randomised or well-matched pilots in foundational literacy and numeracy, publish the results, and expand only what demonstrably works.

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5.**Protect learners.** Adopt data-protection standards and regular bias audits before any platform is deployed at scale.

8. DIRECTIONS FOR FUTURE RESEARCH

Several questions remain open. Do the gains seen in Indian trials replicate in KP's government schools, and for girls as well as boys? Which delivery model works best where connectivity is poor: shared school devices, offline software or teacher-led use of dashboards? How do learners respond to instruction in Pashto or Hindko, and how should adaptive content be designed to support, rather than displace, the mother tongue? Finally, what are the long-term effects on retention and skills after the novelty fades? Answering these requires independent, preferably randomised, evaluations with open reporting.

9. LIMITATIONS

This article is a narrative synthesis and not a new empirical study. Effect sizes come from different populations, subjects and designs, and are not directly comparable. The studies reviewed are drawn chiefly from international and Indian contexts, so extrapolation to KP is an informed judgement and not a measured result. Tables 1 and 3 and Figure 4 reflect our reasoning from the cited literature, not primary data.

10. CONCLUSION

Adaptive AI is neither a cure-all nor a fad. The best available evidence shows that personalised, responsive instruction can raise learning, especially for children who have fallen behind. KP has both the need and, increasingly, the educator interest to benefit. Yet the benefits will not arrive by simply placing software in front of students. They depend on dependable infrastructure, well-prepared teachers, content that speaks the learner's language and values, and a willingness to test every promise against evidence. Done thoughtfully, adaptive AI can support teachers rather than replace them, and bring the individual attention that every child deserves a little closer.

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