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Harnessing Artificial Intelligence for Education Reform in Libya: Opportunities and Challenges

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ABSTRACT

Many education systems are seeking ways to improve teaching quality, personalize learning, and increase administrative efficiency. Libya faces recovery challenges and regional disparities that make scalable solutions especially important. Objective: This study examines how artificial intelligence could contribute to education reform in Libya while safeguarding equity, privacy, and academic integrity. Methods: We conducted a scoping review of recent empirical studies and policy documents, compared implementation frameworks, and completed a Libya-focused desk review on governance, infrastructure, human capacity, and curriculum-aligned content. Results: The synthesis indicates that intelligent tutoring, adaptive practice, automated feedback for low-stakes writing, and responsible data use can support gains in achievement and teacher efficiency when aligned with curriculum and accompanied by sustained professional development. Constraints include uneven connectivity, capacity gaps, and limited high-quality Arabic content; these factors can widen disparities if not addressed. Conclusion: A staged roadmap is proposed that prioritizes national guidance and safeguards, teacher capacity building, targeted pilots in foundational literacy, mathematics, and writing support, and careful scale-up based on evidence and inclusiveness across regions.

INTRODUCTION

Education systems worldwide are exploring artificial intelligence to enhance pedagogy, personalize learning pathways, and streamline school and system management. In Libya, persistent regional disparities, interrupted schooling, and uneven access to technology create an urgent need to raise learning outcomes efficiently while ensuring fairness. Global partners emphasize the importance of strengthening foundational skills and adopting technology as a complement to teachers rather than a replacement. Within this context, Libya has articulated ambitions to modernize public services and develop digital capacity (United Nations Sustainable Development Group, 2022). The central question guiding this paper is how artificial intelligence can be harnessed to advance education reform in Libya without compromising learner safety, privacy, or academic integrity.

This paper contributes in three ways. First, it synthesizes recent evidence on the opportunities and risks of artificial intelligence in education, with emphasis on use cases that are most relevant to Libya(Bond et al., 2024). Second, it maps Libya's readiness through a desk review of governance, infrastructure, teacher capacity, content availability, and data foundations (International Telecommunication Union, 2023; Education Profiles, 2024; UNESCO Institute for Statistics, 2025). Third, it proposes a pragmatic roadmap that sequences policy, capacity building, pilot implementation, and scale-up, aligned with international guidance (UNESCO, 2021; Organisation for Economic Co-operation and Development, 2024, 2025). The intended audience includes policymakers, school leaders, teacher educators, and researchers who are considering adoption pathways that are both effective and ethical.

LITERATURE REVIEW

The empirical base on artificial intelligence in education is increasingly diverse and mixed-method, with several converging insights that are pertinent to Libya's reform agenda. Evidence on intelligent tutoring systems (ITS) and adaptive practice is among the most mature. Recent systematic reviews synthesize dozens of controlled studies and report consistent, moderate gains in achievement when tools are embedded in lesson plans, aligned with curriculum

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standards, and supported by teachers' formative assessment routines (Fodouop Kouam, 2024; Létourneau et al., 2025). These effects tend to be stronger in mathematics and foundational literacy, where problem-solving steps can be modeled and feedback rules are well specified. Meta-systematic reviews in higher education echo these benefits but underline heterogeneity across subjects, designs, and implementation quality, cautioning that technology alone does not guarantee impact (Bond et al., 2024).

Automated assessment and feedback tools form a second strand of the literature. When used for low-stakes writing, practice quizzes, or short constructed responses, automated or AI-supported feedback can reduce teachers' grading burden and provide rapid, individualized guidance on grammar, structure, or misconception patterns. However, the learning value depends on feedback design. Tools that supply targeted prompts, hints, and exemplars encourage revision and metacognition; those that provide direct answers risk short-circuiting cognitive effort and undermining durable learning. Recent syntheses on generative AI specifically warn of performance illusions: short-run gains in assignment quality may coincide with reduced knowledge retention and task persistence if students outsource core thinking to automated systems (Bastani et al., 2024). Consequently, scholars recommend guardrails that keep teachers in control of assessment decisions and position AI as a drafting aide rather than an answer engine.

A third theme concerns teacher roles, professional development, and adoption. Across contexts, the quality of pedagogy mediates the effects of AI tools. Reviews consistently identify teacher professional development (PD) and school-based coaching as prerequisites for impact, particularly in low-resource settings (Organisation for Economic Co-operation and Development, 2024). Effective PD cycles include modeling in classrooms, guided practice, collaborative planning, and feedback focused on formative assessment, differentiation, and academic integrity in the presence of AI. Adoption research frequently draws on technology acceptance and knowledge frameworks, implying that perceived usefulness, ease of use, and technological–pedagogical content knowledge jointly shape sustained classroom use. In practice, school leadership, time for collaborative planning, and access to localized content often determine whether pilots translate into routine practice(Bond et al., 2024). Equity and inclusion are central concerns. Without compensatory measures, AI can widen disparities because connectivity, device availability, language accommodations, and accessible design are unevenly distributed within and across countries (UNICEF, 2024a, 2024b). Program evaluations highlight the value of offline functionality, low-bandwidth modes, shared-device models, and universal design for learning to reach rural learners and students with disabilities. System-level dashboards and early warning systems may help target resources, yet they also raise privacy and surveillance risks if not governed ethically (Organisation for Economic Co-operation and Development, 2024). Libya's own profiles describe regional gaps in connectivity and school safety that must inform any implementation plan.

Policy, ethics, and data governance comprise a fourth body of work. International guidance converges on human-centered, precautionary adoption: articulate permitted uses; ensure transparency and explain ability appropriate to age and stakes; protect learners' data through purpose limitation, security, and parental consent mechanisms; and establish accountability for algorithmic decisions (Holmes & Miao, 2023). For education systems, clear procurement criteria—evidence of impact, accessibility, language coverage, interoperability, and robust privacy protections—are emphasized alongside teacher guidance for academic integrity and assessment fairness. The literature also calls for independent evaluations and public reporting to build trust.

Arabic-medium and Libyan contexts add distinctive requirements. Advances in Arabic NLP are noteworthy, but coverage remains uneven for dialects and subject-specific corpora; bias, error propagation, and accessibility barriers can arise when models are trained on limited or non-representative data (Sawaf et al., 2023). Classroom-ready tools therefore require localization—terminology aligned to Libyan curricula, dialect-aware interfaces, right-to-left rendering, and culturally appropriate examples—plus empirical evaluation in Arabic-speaking classrooms. Regional initiatives and cooperation agreements signal growing attention to these needs and may catalyze resource development relevant to Libya's schools. At the same time, reports on internet use and freedom online suggest variability in access and policy environments that may affect deployment choices and student safety.

Cost-effectiveness and implementation at scale have become increasingly salient. Policy briefs synthesize lessons from digital learning programs: begin with narrow, high-value use cases; integrate with curriculum and teacher workflows; invest in PD and coaching; and sequence infrastructure and governance improvements to protect equity (World Bank, 2024, 2025). Rigorous cost accounting should consider not only licenses and devices but also connectivity, maintenance, training time, content localization, and safeguarding measures. Evidence gaps remain around long-term effects of generative AI on learning behaviors, the comparative value of AI versus non-AI interventions that target the same bottlenecks, and the conditions under which adaptive tools are most effective in Arabic-medium settings. For Libya, these gaps argue for cautious pilots with built-in evaluation before scale.

Taken together, the literature supports a coherent stance for Libya: AI can improve learning and teacher efficiency when it is curriculum-aligned, teacher-led, and accompanied by professional development, localized Arabic content, accessible design, and strong governance. Conversely, weak pedagogy, inadequate infrastructure, and absent safeguards can negate benefits or exacerbate inequalities. This synthesis informs the study's design and motivates three guiding research questions: what opportunities and challenges accompany AI's use in Libyan education; how ready are

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schools, teachers, and data systems to adopt such tools; and which policies and safeguards will enable equitable, ethical implementation across regions.

METHOD

In this section, study setting and scope focuses on Libya's K–12 and early higher education settings, with attention to regional variation across Tripoli, Benghazi, Misrata, and Wadi Al-Shati/Sabha. Public schools are the primary context; selected TVET and first-year university courses are included where feasible to reflect transition into higher education. The scope covers Arabic-medium instruction in foundational literacy, mathematics, and introductory writing courses where AI use cases are most actionable.

Design: We combine (a) a qualitative scoping review and policy analysis; (b) cross-sectional surveys of teachers and students; (c) semi-structured interviews with policymakers, school leaders, and teachers; and (d) a time-bounded pilot of AI-supported learning (6–8 weeks) with pre-/post-assessment. The design emphasizes practical feasibility in low-resource environments while enabling triangulation across data sources.

Sampling and participants: For surveys, a stratified, multi-stage approach selects schools by region (urban/rural), level (primary/secondary), and governance (public/TVET). Anticipated samples: ≈300 teachers and ≈400 students across ~20–24 schools/classes. For interviews, purposive sampling targets ≈25–30 stakeholders (policy officials, school leaders, and teachers). For the pilot, 6–8 intact classes (≈120–160 students) participate, with parallel control classes where feasible.

Power considerations: Power calculations target detection of a standardized mean difference of $d \approx 0.30$ on learning outcomes with $\alpha=0.05$ and $1-\beta=0.80$. Assuming class-level clustering (ICC≈0.05) and 20–25 students per class, 6–8 classes per arm are sufficient for indicative effects using ANCOVA with baseline scores as covariates. These parameters guide—but do not rigidly determine—site selection given operational constraints.

Intervention: The pilot deploys two AI-supported use cases aligned to Libyan curricula: (1) adaptive practice in mathematics or foundational literacy; and (2) structured, low-stakes writing feedback with teacher-controlled settings. Teachers receive a brief orientation (6–8 hours) and weekly coaching (≈30 minutes) focused on lesson integration, formative use of analytics, and academic integrity guidance. Offline or low-bandwidth modes are preferred where connectivity is limited. Teachers remain responsible for grading and high-stakes judgments.

Measures and instruments: Teacher readiness and attitudes are measured with an adapted instrument drawing on technology acceptance and technological-pedagogical knowledge constructs (perceived usefulness, ease of use, self-efficacy, and pedagogical alignment). Student perceptions capture engagement, effort, and perceived usefulness. Learning outcomes use brief curriculum-aligned assessments (math/literacy) administered pre/post. Writing tasks are scored with rubrics emphasizing structure, coherence, and mechanics, with teachers' rubric scores treated as ground truth. Implementation fidelity is tracked via usage logs (minutes/session, items completed, hint usage), teacher activity logs, and a brief observation checklist (lesson alignment, differentiation moves). Equity proxies include device access, connectivity reliability, and disability accommodations.

Data collection procedures: Surveys are administered on paper or via mobile forms depending on connectivity; interviews are audio-recorded with consent and transcribed. Pre-tests occur one week before the intervention; post-tests occur within one week after conclusion. Usage data are collected automatically from the platforms subject to consent and data-minimization. Teacher workload diaries capture time spent on preparation and feedback for a subset of weeks to estimate efficiency changes.

Data management: All personally identifying information is collected only when necessary and stored separately from analytic datasets. Unique study IDs link data sources. Files are encrypted at rest and in transit, with role-based access limited to the research team. De-identified analytic files are retained for replication according to institutional policy.

Analysis plan (quantitative): Descriptive statistics summarize sample characteristics and baseline equivalence. For learning outcomes, ANCOVA models adjust for baseline scores; where class clustering is material, hierarchical linear models nest students within classes. If parallel control classes exist, difference-in-differences estimates are computed. For binary adoption outcomes (e.g., regular tool use), logistic regression is used. Teacher workload changes are analyzed with paired t-tests or mixed models across diary weeks. Missing data are handled via multiple imputation if missing at random assumptions are plausible; sensitivity checks compare listwise deletion.

Analysis plan (qualitative): Interview and open-ended survey responses undergo thematic analysis using a hybrid coding approach (a priori codes from the framework plus inductive codes). Two coders independently code a subset of transcripts to establish inter-rater agreement (target Cohen's $\kappa \geq 0.75$), reconcile discrepancies, and refine the codebook before full coding. Memos and matrices support cross-case synthesis by region and school level.

Validity, reliability, and trustworthiness: Instrument reliability is assessed with internal consistency (Cronbach's $\alpha \geq 0.70$ as a benchmark) and, where feasible, test–retest on a small subsample. Construct validity is examined via exploratory factor analysis for adapted scales. For qualitative components, credibility is enhanced through triangulation (surveys, interviews, and logs), member checks with participating teachers, and an audit trail of coding decisions.

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Ethical considerations: Participation is voluntary with written consent (and parental consent for minors). No high-stakes decisions rely on AI outputs. Academic integrity guidelines are communicated to students; generative tools are restricted to low-stakes drafting support with disclosure. Data collection adheres to privacy and security principles (purpose limitation, data minimization). Any risks related to connectivity or school safety are addressed through flexible scheduling and offline modes.

Limitations and risk management: As a non-randomized, time-bounded pilot, causal inference is limited; results are indicative, not definitive. Implementation variability and potential measurement error are anticipated and mitigated via fidelity tracking, covariate adjustment, and sensitivity analyses. Regional disruptions may affect continuity; contingency plans include asynchronous tasks and make-up sessions.

Timeline and deliverables: Month 1—instrument finalization, approvals, and teacher orientation; Months 2–3—pilot implementation with coaching and mid-course checks; Month 4—post-testing and interviews; Month 5—analysis and reporting, including policy brief with equity-focused recommendations.

RESULT

Learning outcomes and teacher workload: Across the synthesized evidence and the Libya-focused readiness scan, curriculum-aligned intelligent tutoring and adaptive practice consistently coincide with improvements on short-cycle assessments in mathematics and foundational literacy when teachers embed the tools into lesson plans and formative routines. Teachers report reduced time on routine marking and greater capacity for targeted feedback when automated feedback is limited to low-stakes tasks and teachers retain authority over high-stakes judgments (Létourneau et al., 2025; Bond et al., 2024). In the proposed pilot, baseline equivalence checks and post-test comparisons are designed to detect small-to-moderate gains after 6–8 weeks; any imbalances are addressed through ANCOVA models controlling for pre-test scores.

Implementation fidelity and usage patterns: Platform logs and observation checklists are used to gauge fidelity. In similar deployments, higher learning gains are associated with regular weekly use, adequate item completion, and teacher-prompted reflection (e.g., “explain-why” hints) rather than answer-giving. The planned fidelity indicators include minutes per week, items completed, hint usage ratios, and alignment with the intended lesson focus. Qualitative notes from coaching sessions document common challenges (e.g., pacing with mixed-ability classes, students over-relying on generated text) and effective teacher moves (e.g., requiring students to annotate steps or compare model solutions with their own).

Equity and access: Readiness indicators point to meaningful regional variation in connectivity, device access, and school safety (International Telecommunication Union, 2023; DataReportal, 2024; Global Coalition to Protect Education from Attack, 2024). In the pilot design, offline or low-bandwidth modes and shared-device rotations are incorporated to protect participation. Monitoring focuses on whether usage and outcomes differ by region, school type, or disability status proxies (self-reported accommodations), with corrective actions triggered where gaps appear.

Language and content adequacy: The synthesis highlights gaps in Arabic-medium and Libya-aligned content. Screening criteria for pilot tools require right-to-left rendering, Arabic and dialectal support, curriculum alignment, and accessible design. Teacher judgments and student feedback on content relevance are recorded as part of implementation data. Any systematic content mismatches are logged for vendor remediation or replacement.

Data governance readiness: Schools’ data practices and platform controls are assessed against minimum safeguards: purpose limitation, consent, data minimization, storage location, role-based access, transparency, and auditability. During the pilot, dashboards are configured for formative use only; no punitive or high-stakes decisions are derived from automated analytics. Incidents are recorded and reviewed by the project’s ethics focal point.

Feasibility and cost notes: Resource tracking distinguishes one-off setup tasks (orientation, configuration) from recurring tasks (coaching, maintenance). Cost notes catalogue license or hosting fees, teacher time for preparation and review, and connectivity costs. These descriptive records support later cost-effectiveness analysis and procurement guidance as shown in Table 1.

Table 1. AI tool categories, typical benefits, key risks, and recommended guardrails

AI tool category	Typical benefits	Key risks	Recommended guardrails
Intelligent tutoring & adaptive practice	Achievement gains in math and foundational literacy; timely feedback	Over-reliance; misalignment with curriculum	Teacher oversight; curriculum alignment; explain-why hints
Automated feedback for low-stakes writing & quizzes	Reduced grading time; individualized formative feedback	Shallow learning; bias in automated scoring	Use for formative tasks only; rubrics; human review
Generative assistants for drafting & coding	Brainstorming support; language scaffolds	Plagiarism; hallucinations; reduced	Academic integrity policies; disclosure; cite and verify

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		effort	
Dashboards & early-warning systems	Targeted support; better resource allocation	Privacy risks; punitive misuse	Data minimization; role-based access; clear purpose limitations

DISCUSSION

Interpretation of learning and workload patterns: The short-cycle gains associated with intelligent tutoring and adaptive practice are consistent with prior syntheses, particularly when teachers integrate the tools into formative assessment and require students to explain their reasoning (Létourneau et al., 2025). Reductions in routine marking free teacher time, but the net benefit depends on high-quality prompts, alignment to lesson objectives, and professional judgment on when to rely on automated feedback (Bond et al., 2024). Absent these conditions, apparent performance gains can mask shallow learning (Bastani et al., 2024; Chen et al., 2025).

Theory of change and role of teachers: A teacher-centered theory of change positions AI as a scaffold for practice, feedback, and differentiation—not as a source of final answers. Key mechanisms include timely formative information, individualized pacing, and structured hints that support metacognition. Effective implementations retain teacher authority over task design, grading, and classroom norms for integrity. Coaching cycle's help teachers adapt prompts, set boundaries for generative tools, and interpret dashboards for supportive—not punitive—interventions.

Equity lens: Differential access to devices and connectivity can widen gaps unless compensated by offline modes, shared-device rotation, and in-class facilitation. Accessibility features (screen readers, adjustable text, vocabulary scaffolds) are essential for learners with disabilities. Monitoring should disaggregate participation and outcomes by region and school type to surface inequities early and direct support where it is most needed (UNICEF, 2024a, 2024b; International Telecommunication Union, 2023; DataReportal, 2024).

Governance, integrity, and safety: Clear rules for consent, data minimization, storage, transparency, and role-based access reduce privacy risks and build trust (UNESCO, 2021; OECD, 2025). Academic integrity policies should specify acceptable support (e.g., drafting outlines, language scaffolds) versus prohibited uses (e.g., answer generation), along with disclosure expectations. Vendors should provide explain ability features and logs that enable auditing without exposing personal data.

Feasibility and cost-effectiveness: The practicality of adoption improves when procurement requires offline or low-bandwidth functionality, curriculum alignment, and teacher-facing supports. Budget planning should include professional development and coaching time—not just licenses and devices. Descriptive cost records from pilots can inform value-for-money comparisons against alternative, non-AI interventions targeting the same bottlenecks.

Limitations and external validity: As designed, the pilot provides indicative, context-specific results rather than definitive causal claims. Effects may vary by region, subject, and teacher experience. Nonetheless, triangulation across usage logs, assessments, and interviews strengthens confidence in patterns and informs adaptive scaling.

Policy and practice implications: (1) adopt national guidance that defines permitted uses, privacy and integrity guardrails, and procurement criteria; (2) invest in sustained teacher PD and school-level coaching; (3) prioritize pilots in foundational literacy, mathematics, and low-stakes writing feedback; (4) fund development of Arabic and dialect-aware resources aligned to Libyan curricula; and (5) monitor equity and safety with a standardized evaluation framework before scaling.

CONCLUSION

This study synthesizes recent evidence and Libya-specific readiness insights to outline how artificial intelligence can support education reform when implemented with strong pedagogy, governance, and equity measures. Across the reviewed literature and proposed pilot framework, the most promising near-term uses center on adaptive practice in foundational subjects and structured, teacher-mediated writing feedback. These uses show potential to improve learning while easing routine workload, provided teachers maintain control of assessment and classroom norms.

Three priorities emerge for Libya: first, adopt clear national guidance on privacy, integrity, and procurement to create an enabling environment; second, invest in sustained professional development and coaching that equips teachers to integrate tools into formative assessment and differentiation; third, target resources toward connectivity, devices, and accessible, Arabic-aligned content to ensure that benefits reach all learners, including those in underserved regions and students with disabilities. A staged, evidence-based scale-up—grounded in transparent evaluation—offers a feasible path to sustainable improvement. Future work should extend pilots across additional regions and subjects, refine localized content and accessibility features, and compare cost-effectiveness against non-AI alternatives addressing the same instructional goals. With careful sequencing and safeguards, AI can be a practical lever to advance equitable learning in Libya

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