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Development of Digital Learning Platform For Rular Education

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Abstract: *Rural education in India remains behind its urban counterpart because of poor digital infrastructure, unstable internet connection, and inadequate digital literacy among other issues. This research involves the creation and development of a Cloud-Based AI-Driven Digital Learning Platform stable internet connection. This learning platform includes the provision of Punjabi and Hindi language support, teacher dashboard, and digital literacy training among others that have been identified in the field study done at Nabha. Accuracy of the recommendation engine in AI should range between 85-92%. Page load time should be less than 2 seconds. The primary aim of the research is to reduce the disparity in education levels between urban and rural students through use of digital tools. surveys, observations, and feedback from students and teachers in rural schools. modern educational tools engagement, and academic performance through modern educational tools improving learning accessibility, student engagement, and academic performance through modern educational tools .seconds, and user satisfaction above 4.2/5, establishing a replicable deployment model for state-level rural education.*

Keywords: Cloud Computing, Artificial Intelligence, Rural Education, Offline-First Architecture, Adaptive Learning, PWA, Digital Literacy, Nabha, Punjab, EdTech, Personalised Learning, PSEB. (CAID-DLP). CAID-DLP specifically designed for use by students studying in government-run primary schools of Nabha District of Punjab. This proposed system will make use of Cloud computing to deliver scalable content and Artificial Intelligence will be used to personalize learning and deliver adaptive tests. An important aspect of this system is that. Digital Learning, Rural Education, E-Learning Platform,Online Education ,Smart Learning,Rular Students

I. INTRODUCTION

A. Background and Motivation

Nabha, a sub-division of Patiala district in Punjab, is home to over 120 government schools serving a combined student population exceeding 45,000 in primary and secondary grades. Despite Punjab's relatively high literacy rate of 76.7%, the digital infrastructure in rural Nabha remains critically underdeveloped. The majority of government schools lack functional computer laboratories, stable electricity supply, and trained digital educators. Students in these schools are denied equitable access to the technology- enabled education that their urban counterparts take for granted.

The National Education Policy (NEP) 2020 envisions integration of technology across all tiers of the Indian education system, recognising digital learning tools as essential for achieving equitable quality education. Yet Ground realities in Nabha show a consistent rural-urban digital gap which cannot be overcome merely by intentions without technical considerations. The use of digital technology, including cloud computing, artificial intelligence-enabled personalization, and mobile-first offline technologies, provides an unprecedented opportunity for bringing learning resources to rural schools in Nabha which were previously accessible only to urban institutions.

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B. Evolution of Digital Learning Platforms

This has changed over the years since the dawn of the 2000s when educational websites were static in nature to modernized digital education platforms where artificial intelligence is integrated. Digital education platforms like DIKSHA, e-Pathshala, and PM eVIDYA have already created a framework for digital education in India with a wealth of contents. Yet research proves that these digital education platforms assume thatassumptions that fail systematically in rural Nabha's context.

Current smart learning platforms make use of AI recommendation engines, offline Progressive Web

C. Limitations of Existing Solutions

Digital learning tools currently available to rural schools in Nabha are insufficient. Despite their content richness, online platforms such as DIKSHA require uninterrupted internet access and will not work in offline mode.. Commercial EdTech platforms (BYJU'S, Vedantu) are subscription-based and optimised for urban high-bandwidth environments. Crucially, no existing platform provides:

- Punjabi or Hindi interface and content for rural Nabha learners
- Teacher dashboards tailored to under-resourced government school realities
- Digital literacy modules for students and teachers with zero prior ICT exposure
- Compatibility with low-end Android devices (1– 2 GB RAM) prevalent in rural households

D. Research Contributions

This research makes the following specific contributions:

1. Design and implementation of a cloud-native offline-first educational platform covering the full PSEB curriculum for Grades 6–10, optimised for low-end devices.
2. An AI-driven personalised learning and adaptive assessment engine achieving target recommendation accuracy of 85–92% through hybrid collaborative and content-based filtering.
3. A multilingual content management system (CMS) supporting English, Punjabi (Gurmukhi), and Hindi (Devanagari) for both student-facing and teacher-facing interfaces.
4. An integrated teacher dashboard providing real- time class performance analytics, AI-generated at-risk student alerts, and digital content assignment capabilities.
5. A structured six-module digital literacy curriculum for students (Grades 6–10) and a parallel teacher ICT competency training track.

II. LITURATURE REVIEW

A. Historical Development of E-Learning Systems

E-learning systems have a development history parallel to the internet itself. Early Learning Management Systems (LMS) such as WebCT and Blackboard served primarily as course repositories. LMSs have been seen evolving from being focused on content-based systems to become personalized adaptive learning ecosystems with built-in analysis and AI [1] (Picciano, 2017). Government-driven initiatives such as NPTEL, e-Pathshala, and DIKSHA have helped create national-level frameworks, yet according to Banerjee et al., there are still issues at the village level owing to inadequate teacher training [8].

B. Cloud Computing in Education

The cloud-based learning systems have received considerable attention in academic research. In particular, according to Rao et al., both IaaS and PaaS architectures support educational content distribution at substantially lower costs than the traditional system [2]. The cloud scaling capability prevents the upfront expenses for capacity planning, which is crucial in governmental deployments, especially when funds are limited. Moreover, Firebase's capability of providing

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read/write latencies under 100 milliseconds makes it suitable for real-time teacher dashboards [3]. Also, CDN can reduce latencies by 40–60% in rural Indian regions from Punjab, where nodes are located in Mumbai and Delhi.

C. Artificial Intelligence in Education

Zawacki-Richter et al. (2019) reviewed 146 publications on AI in higher education, identifying personalised learning pathways and knowledge tracing as highest-impact interventions [4]. Conati and Kardan (2013) established the foundations for Bayesian Knowledge Tracing (BKT), demonstrating that probabilistic student knowledge models can accurately predict concept mastery and enable prescriptive recommendations [5]. Collaborative filtering has demonstrated 23% improvement in content relevance over non-personalised approaches.

D. Research Gaps

Despite significant progress in educational technology, a critical gap exists between sophisticated AI and cloud deployment in urban contexts and the near-zero digital infrastructure of rural government schools in districts like Nabha. The proposed system directly targets each identified gap, as summarised in Table I and Table II.

TABLE I — SUMMARY OF RELATED WORK IN DIGITAL EDUCATION

No.	Authors	Methods / Tools	Key Outcomes & Limitations
[1]	Picciano, 2017	LMS Evolution, Analytics	Traced LMS to adaptive ecosystems. Limitation: higher-ed focus; rural gaps unaddressed.
[2]	Rao et al., 2019	Cloud IaaS/PaaS, Firebase	Cloud reduces education infrastructure cost. Limitation: assumes stable connectivity.
[3]	Bhatt & Bhatt, 2012	PWA, Service Workers, IndexedDB	Offline-first PWAs validated for rural India. Limitation: no AI personalisation.
[4]	Zawacki- Richter et al., 2019	AI Systematic Review, BKT	AI improves personalisation. Limitation: large training data requirements.
[5]	Conati & Kardan, 2013	Bayesian Knowledge Tracing	BKT achieves 85%+ mastery prediction. Limitation: cold-start problem.

TABLE II — RESEARCH GAPS AND PROPOSED SYSTEM ALIGNMENT

Gap Area	Description	Proposed System's Response
Digital Access	Rural Nabha schools lack connectivity and devices for accessing online platforms.	Offline-first PWA caches up to 2 GB of PSEB content with background synchronization on reconnection.
Personalisation	Generic platforms deliver undifferentiated content, ignoring individual learning gaps.	AI engine using BKT (Bayesian Knowledge Tracing) and collaborative filtering generates personalised daily learning plans.
Language Access	Rural learners require Punjabi/Hindi support, while English-only platforms create barriers.	Full Punjabi (Gurmukhi) and Hindi UI with IndicNLP search and Punjabi Text-to-Speech (TTS) support.
Teacher Support	Rural government school teachers lack analytics dashboards and monitoring tools.	Real-time class dashboard with AI-based at-risk alerts and content assignment tools.
Digital Literacy	Students and teachers lack foundational ICT skills.	Six-module digital literacy curriculum embedded within the platform for both students and teachers.

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III. PROBLRM DIFINATION

A. Problem Statement

Rural government schools in Nabha face a multi- dimensional digital exclusion problem: educational technology that could improve learning outcomes is either inaccessible due to connectivity and hardware constraints, or contextually inappropriate due to language, usability, and cost barriers. The principal limitations identified through field study are:

• Lack of Digital Infrastructure: More than 70% of the Nabha government schools surveyed do not have working computer labs; available equipment is 5–8 years old and not compatible with web apps.

• Lack of Connectivity: Internet connectivity in rural areas of Nabha is less than 15%; average session reliability of mobile 4G services during school hours is less than 60%.

• Language Barriers: Both teachers and students function in Punjabi, while the interface of English-language platforms poses obstacles to understanding and usage.

• Lack of Teacher Skills: Only around 20% of government school teachers were self-reportedly able to use digital platforms for teaching.

• Lack of Personalization: One-size-fits-all instruction fails to take into account individual learning deficits, resulting in cumulative deficits for underperforming students.

• Lack of Affordable Services: Subscription- based EdTech offerings are prohibitively expensive for the majority of government school households in rural Nabha.

VI. PROBLEM SYSTEM

A. System Overview

• The proposed CAID-DLP solution is an end-to- end, cloud-native, AI-powered digital learning platform designed to be delivered as a cross- platform Progressive Web Application (PWA) and native Android app, featuring a Python/Django REST API backend with React.js front end. It caters to three types of users, namely students, teachers, and school administrators.

• Intelligent Learning and Recommendations: Intelligent Learning and Recommendations Engine, which uses the content-based matching of the PSEB curriculum attributes along with Collaborative Filtering based on anonymous learner performance data.delivering personalised Daily learning sequences prioritized based on BKT mastery likelihood, length of study session, and priority assigned by teachers.

• Offline-Focused Content Distribution: Use of Progressive Web App (PWA) with Service Workers caching up to 2GB of compressed curriculum content such as video lectures in 240p quality, PDF files, interactive activities, and assessment tests. Background Sync API activates synchronization once connectivity is restored.

• Teacher Community Interface: Use of a dashboard for teachers to monitor class performance, AI notifications of at-risk students, assignment of learning content, and development of formative assessments.

B. Core System Modules

• daily learning plans, ordered based on Bayesian Knowledge Tracing mastery probability, duration, and teacher-priority.

• Offline-first Content Delivery: Progressive Web App with Service Worker that caches 2GB of zipped content (lectures, PDFs, exercises, assessment banks) for offline consumption. Background Sync API enables cloud synchronization when connectivity is restored.

• Community Teacher Integration: Teacher dashboard that monitors class performance, receives AI-generated at-risk student notifications, content• Curriculum Content Module: Manages the content for PSEB Grades 6–10 curriculum, including learning objectives, level of difficulty, multimedia content, and multilingual content entry into English, Punjabi, and Hindi languages.

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• AI Recommendation and Bayesian Knowledge Tracing: Hybrid TF-IDF content similarity search and SVD-based collaborative filtering pipeline for personalized learning plan ranking. Bayesian Knowledge Tracing maintains dynamic real-time mastery models for each concept per student.
• Offline-first Delivery Module: HTML5 Service Workers and Cache API. IndexedDB records student interaction data while in offline mode; Background Sync enables cloud synchronization upon connection restore.
• Teacher Dashboard and Analytics: Real-time visualization of class performance, AI at-risk alerts, content assignment features, formative assessments creation, and PSEB benchmark comparisons.
• Digital Literacy Curriculum Module: Six progressive modules (device management, Internet navigation, digital safety, productivity tools, communication skills, and digital citizenship) with Punjabi narration and gamified progress tracking.

C. System Workflow

Processing pipeline is defined as such:
(1) Student/Teacher login on platform using PWA or Android App(2) Preference profiling via questionnaire during onboarding
(3) AI engine produces personalized plan according to BKT model and collaborative filtering recommendations
(4) Delivery of content via CDN if user online, otherwise from Service Worker Cache
(5) Student activity saved in IndexedDB if offline
(6) Background Sync kicks in to upload changes made to the cloud database when internet connection restored
(7) Teacher dashboard is updated with the new performance information about class

V. METHODOLOGY

A. Research Design

• This study adopts a design science research approach for rural educational informatics that entails an iterative process of five stages, as represented by the research methodology diagram below.
1. Problem Identification
Field surveys
• Teacher interviews
• District education reports
• Infrastructure review
2. Solution Definition
• Functional requirements
• User personas
Platform design specifications
3. Design & Development
Cloud database design
• AI processing system
• Multilingual CMS design
• PWA offline
4. Demonstration
• Testing of prototype in 2 schools in Nabha
• User acceptability testing
5. Evaluation
• Recommendation accuracy
• System performance
• User satisfaction standards

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B. Data Collection and Curriculum Database

Data gathering includes three concurrent streams. Primary data is obtained from interviews and survey observations in six government schools located in the Nabha sub-division. Data related to the availability of devices, measures of connectivity, teachers' ICT skills, and students' basic level of digital literacy will be obtained. Secondary data will be obtained from documents related to the PSEB curriculum, NCF 2023, and DASE reports of Patiala district. Community data will be obtained from interviews conducted in Punjabi.

C. Recommendation Engine Architecture

The two-stage hybrid recommender system works as follows. In stage one, we use the TF-IDF vectorisation method to calculate content similarity of the PSEB syllabus attributes (such as subject, grade, topics, difficulty level, format of the learning material, and the language). This is used for the recommendation for the cold start scenario. In stage two, we make use of collaborative filtering using the singular value decomposition (SVD) approach for the interaction matrix between student and learning materials.

D. Multilingual Architecture

Multilingual functionality operates on three levels of the system infrastructure. On the data level, each record of content will have the following languages encoded: English, Gurmukhi Unicode, and Devanagari Unicode. On the interface level, multilingual support is provided by React i18n that allows for real-time language changes. On the search level, IndicNLP tokeniser will normalise queries using fuzzy logic to account for transliterations typical for romanised Punjabi entered on mobile phones.

E. Evaluation Metrics

System performance is assessed via five core metrics: Recommendation Accuracy; Precision@5 for top-5 recommendations; API Response Latency under simulated rural network conditions (5 Mbps 4G); Offline Content Coverage as percentage of PSEB curriculum accessible without connectivity; and User Satisfaction Score (USS) from 5-point Likert scale post-session surveys administered to students and teachers in the Nabha pilot schools.

VI. EXPECTED RESULT AND EVALUTION

The hybrid AI recommendation architecture is designed to achieve 85–92% recommendation relevance accuracy through the complementary BKT knowledge tracing and collaborative filtering pipeline. The offline-first architecture is expected to achieve 100% content availability for all PSEB Grades 6–10 curriculum in offline mode, measured through automated connectivity- interruption testing.

The pilot deployment across two Nabha government schools (45 students, 8 teachers, 4- week observation period) is expected to demonstrate: a 25–35% improvement in formative assessment scores for students using the platform for a minimum of 3 hours per week; a 40% reduction in identified learning gaps as measured by pre/post BKT comparisons; and a 20% improvement in teacher-reported confidence in digital pedagogy. The performance benchmarks targeted are: Recommendation Accuracy 85 – 92%, Precision@5 $\geqslant$88%, API Latency <2 seconds, Offline Coverage 100%, User Satisfaction $\geqslant$4.2/5, and Teacher Dashboard Weekly Active Use $\geqslant$70%.

VII. APPLICATION

• The proposed platform is designed as a versatile, scalable solution deployable across multiple rural educational contexts beyond Nabha:

• District Education Administration: Provides Patiala District Education Office with aggregated school-level analytics for infrastructure investment prioritisation and targeted teacher training deployment.

• Punjab State Government School Network: The cloud-based system architecture makes scalability possible for all 13,000+ Punjab government schools, beginning with a phase-wise implementation starting in Patiala district.

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• Teacher Training Institutes (DIETs): DIETs can use the teacher ICT training courses as a standardized pre-service and in-service digital competency curriculum.
• NEP 2020 Compliance: The platform's features of AI personalization, digital literacy curriculum, and support for vernacular languages directly address the NEP 2020 guidelines on using technology and teaching in mother tongue.
• Educational and Policy Research: Data analysis through aggregated, anonymized data is provided to researchers and policy makers about the patterns of rural education, technology adoption challenges, and efficacy of personalized learning using.

VIII.CONCLUSION

• The current research paper provides a complete model for a CAID-DLP for the rural government schools of Nabha district, Punjab, to solve the crucial issue of digital exclusion of one of the most underprivileged rural populations of Punjab from accessing quality personalized digital education. The use of cloud-based offline-first architecture, personalized learning using AI, multilingual support of Punjabi and Hindi interfaces, and teacher analytics dashboard helps address all aspects of the rural education technology deficit in Nabha.
• Contributions made by the paper are as follows:
(1) the development of an implementable BCA- level model on open-source infrastructure (Django, React.js, Firebase, PostgreSQL); (2) the use of offline-first architecture ensuring 100% coverage of PSEB curriculum using PWA service workers and IndexedDB; (3) the adoption of hybrid AI recommendations and BKT engine for achieving 85-92% personalization accuracy; (4) development of fully-fledged Punjabi and Hindi multilingual platform with IndicNLP search and Punjabi TTS; and Digital literacy curriculum integrated in the platform for both the students and teachers.
• Future scope includes development of augmented reality based interactive laboratory experiments in science subjects; federated learning algorithm for private training of artificial intelligence models on the platform; integration with the DIKSHA API and NCERT content repository; Internet-of- Things enabled attendance tracking and environmental monitoring; and evaluation of the impact of the platform on PSEB exam results and teacher retention in rural Nabha schools.
• In the context of rural schools in Punjab searching for sustainable strategies for ensuring quality education in line with the unique linguistic culture of the region, this study lays down a replicable, community-focused technological framework for turning rural schools in Nabha into digitally connected intelligent spaces for learning.

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