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Artificial Intelligence for Enhancing STEM Education in Tripura: Opportunities, Challenges, and Strategies for Developing Future-Ready Learners

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ABSTRACT

Artificial Intelligence (AI) has significant potential to transform Science, Technology, Engineering, and Mathematics (STEM) education by enabling personalized learning, virtual laboratories, intelligent tutoring, automated assessment, and data-driven academic support. This study examines the opportunities, challenges, and strategic requirements for integrating AI into STEM education in Tripura. A quantitative and explanatory research design was adopted, using primary data collected from 450 teachers and students of selected government and private schools. The study applied descriptive statistics, reliability analysis, Confirmatory Factor Analysis, and Structural Equation Modelling using AMOS. The findings show that the proposed model achieved an acceptable to good fit (CMIN/DF = 1.596, RMR = 0.032, GFI = 0.906, AGFI = 0.886, and PGFI = 0.743). Opportunities of AI ($\beta = 0.382$, $p < 0.001$), AI Infrastructure Readiness ($\beta = 0.362$, $p < 0.001$), and Policy and Institutional Support ($\beta = 0.318$, $p = 0.013$) significantly and positively influenced Future-Ready Learning. AI awareness, AI teaching and learning, teacher readiness, student readiness, and adoption challenges showed no significant direct effects. The study concludes that equitable infrastructure, recognition of AI opportunities, and institutional support are essential for building future-ready STEM learning in Tripura.

Keywords: *Artificial Intelligence, STEM Education, Future-Ready Learning, AI Infrastructure, Tripura, Policy Support.*

1. Introduction

Artificial Intelligence (AI) has emerged as one of the most transformative technological innovations of the twenty-first century, reshaping the way individuals learn, communicate, work, and solve problems across diverse sectors. In education, AI has gained significant attention because of its ability to personalize learning experiences, automate routine instructional tasks, provide intelligent tutoring, facilitate data-driven decision-making, and enhance student engagement. Science, Technology, Engineering, and Mathematics (STEM) education, which emphasizes analytical thinking, innovation, experimentation, and problem-solving, has become one of the most promising domains for AI integration. The convergence of AI and STEM education has created unprecedented opportunities to develop future-ready learners equipped with the digital competencies, computational thinking skills, creativity, and adaptability required in the rapidly evolving knowledge economy *(Krishnamurthy, 2025)*. Recent educational reforms worldwide have therefore increasingly emphasized AI literacy, digital transformation, and technology-enabled learning as essential components of quality education.

The growing significance of AI in education has been reinforced by rapid technological advancements, widespread internet accessibility, cloud computing, big data analytics, machine learning, and intelligent educational platforms. Traditional classroom instruction has often struggled to accommodate diverse learning abilities, individual learning styles, and varying academic needs. AI-driven educational technologies have addressed many of these limitations by providing adaptive learning environments that continuously analyse learner performance and recommend personalized instructional pathways. Intelligent tutoring systems, automated assessments, predictive learning analytics, virtual laboratories, conversational chatbots, and AI-assisted content generation have transformed conventional teaching methodologies into interactive and learner-centred educational experiences (*Mundhe, 2025*). Such innovations have improved student participation, reduced teachers' administrative workload, and enabled continuous monitoring of learning outcomes.

Globally, governments and educational institutions have recognized STEM education as a critical foundation for technological innovation, scientific advancement, and economic competitiveness. Countries investing substantially in STEM education have demonstrated greater technological capacity, industrial productivity, and research excellence. However, several developing regions continue to face challenges in delivering high-quality STEM education because of inadequate infrastructure, limited laboratory facilities, teacher shortages, insufficient digital resources, and unequal educational opportunities. AI has increasingly been viewed as a strategic solution capable of overcoming many of these barriers through virtual experimentation, intelligent instructional systems, remote learning platforms, automated feedback mechanisms, and adaptive curriculum delivery (*Vaidya, 2024*). Through making STEM learning more interactive, accessible, and personalized, AI has the potential to bridge educational inequalities while improving students' conceptual understanding and practical competencies.

Within the Indian context, the adoption of AI in education has gained momentum following the implementation of the National Education Policy (NEP) 2020, which strongly advocates technology-enabled learning, multidisciplinary education, competency-based curriculum, digital literacy, and experiential learning. National initiatives such as Digital India, PM eVIDYA, DIKSHA, SWAYAM, UDISE+, and other digital education platforms have created an enabling ecosystem for integrating advanced technologies into school education. These initiatives have improved access to digital educational resources, strengthened educational governance, and promoted personalized learning opportunities across different educational settings (*Raghuvanshi & Dwivedi, 2025*). Simultaneously, AI has begun supporting educational administration through intelligent data management, student performance monitoring, resource optimization, and decision-support systems, thereby contributing to improved educational efficiency and accountability.

Despite these encouraging developments, the implementation of AI-based STEM education remains uneven across different Indian states, particularly in geographically isolated and socio-economically disadvantaged regions. The northeastern state of Tripura presents a unique educational context characterized by rich cultural diversity, tribal populations, rural settlements, and varying levels of digital infrastructure. Although educational indicators have improved considerably over recent decades, disparities continue to exist in terms of access to advanced digital technologies, internet connectivity, teacher preparedness, laboratory facilities, and STEM learning opportunities. Many schools continue to experience infrastructural limitations that restrict effective implementation of technology-enabled teaching practices. Consequently, students in rural and tribal areas may face greater challenges in acquiring AI-related competencies compared to their counterparts in urban educational institutions.

The integration of AI into STEM education in Tripura therefore represents both an opportunity and a challenge. On one hand, AI can provide personalized instruction, intelligent assessment, virtual laboratories, adaptive simulations, automated content delivery, and multilingual educational support that addresses diverse learner needs. AI-powered educational technologies can particularly benefit remote schools by compensating for shortages of specialized STEM teachers and laboratory infrastructure.

Virtual experimentation, intelligent tutoring systems, and AI-enabled simulations can provide students with authentic scientific learning experiences regardless of geographical location. Furthermore, AI applications supporting local languages and culturally responsive instructional content may contribute to improving educational inclusion among tribal communities.

On the other hand, successful implementation of AI in Tripura's educational system depends upon several critical enabling factors, including reliable digital infrastructure, uninterrupted electricity supply, affordable internet access, teacher digital competence, institutional readiness, supportive educational policies, cybersecurity measures, ethical AI practices, and continuous professional development. Teachers remain central to successful AI integration because educational technologies can complement but not replace effective pedagogical practice. Professional training programmes are therefore essential to equip educators with the knowledge and confidence required to effectively utilize AI-based teaching tools while maintaining student-centred instructional approaches (*George, 2024*). Additionally, issues relating to algorithmic bias, student privacy, data security, responsible AI usage, and equitable technology access require careful policy attention before large-scale implementation.

Research has increasingly demonstrated that AI-supported STEM education significantly enhances higher-order cognitive skills, computational thinking, creativity, scientific inquiry, collaborative learning, and problem-solving abilities. Educational robotics, coding platforms, intelligent programming environments, and AI-based project learning have encouraged students to actively participate in experimentation rather than merely memorizing theoretical concepts. In a study conducted among rural schools in Assam, the integration of AI and educational robotics significantly improved students' self-efficacy, technical understanding, innovative thinking, and STEM engagement, demonstrating that technology-supported learning can be successfully implemented even in resource-constrained educational environments when appropriate support mechanisms are provided (*Gaur & Kalita, 2024*). These findings suggest similar possibilities for enhancing STEM education in Tripura through carefully planned AI integration strategies.

Artificial Intelligence also contributes significantly to inclusive education by supporting learners with diverse educational needs. Speech recognition, text-to-speech systems, language translation, adaptive interfaces, personalized feedback mechanisms, and assistive technologies enable students from different linguistic, cultural, and learning backgrounds to participate more effectively in STEM learning. AI-powered analytics further assist educators in identifying struggling learners at an early stage, allowing timely academic interventions that improve learning outcomes. Such capabilities are particularly relevant for states like Tripura, where educational diversity requires flexible instructional approaches capable of accommodating multilingual classrooms and varied socio-economic backgrounds.

Nevertheless, several challenges continue to limit AI adoption in Indian school education. Limited funding, inadequate ICT infrastructure, insufficient teacher training, resistance to technological change, curriculum rigidity, ethical concerns, and the digital divide remain significant obstacles. Rural schools often experience inconsistent internet connectivity, limited access to digital devices, and shortages of technically trained personnel capable of maintaining AI-enabled educational systems. These challenges are even more pronounced in remote regions where educational resources remain unevenly distributed. Consequently, there is an urgent need to develop context-specific strategic frameworks that address infrastructural limitations while promoting equitable AI adoption across diverse educational settings.

2. Reviews of Literature

Sl. No.	Author(s) & Year	Study Title / Focus	Methodology	Major Findings	Research Gap
1	Raghuvanshi & Dwivedi (2025)	E-governance and digital transformation in Indian education	Case study and policy analysis	Digital initiatives such as DIKSHA, UDISE+, and Digital India improved governance, educational access, and transparency. Infrastructure and teacher training remained major constraints.	Limited emphasis on AI-supported STEM education in northeastern states such as Tripura.
2	Krishnamurthy (2025)	AI and future-ready education	Conceptual analysis	AI is transforming labour markets, requiring curriculum reforms, interdisciplinary education, and AI literacy.	Did not examine AI implementation at the school level in rural Indian contexts.
3	Mundhe (2025)	AI applications in teaching and learning	Thematic review of secondary studies	AI supports adaptive learning, intelligent tutoring, formative assessment, and inclusive education while reducing teachers' workload.	Lacks empirical evidence regarding AI adoption in school STEM education in northeastern India.
4	George (2024)	AI readiness in Indian engineering education	Policy and survey analysis	AI-integrated curriculum, project-based learning, and software skills improve employability. Engineering education requires major reforms.	Focuses mainly on higher education rather than school STEM education.
5	Gaur & Kalita (2024)	AI and robotics in STEM education	Experimental case studies in Assam schools	Robotics and AI significantly improved students' self-efficacy, technical knowledge, creativity, and problem-solving skills.	Conducted only in Assam; similar studies are unavailable for Tripura schools.
6	Vaidya (2024)	AI integration in STEM education across South Asia	Review study	AI enhances accessibility, personalized learning, research capability, and regional collaboration in STEM education.	Does not provide region-specific implementation strategies for Indian states.
7	Khan et al. (2023)	Artificial Intelligence and Human-Computer Interaction	Edited research volume	Integration of AI and HCI improves intelligent educational systems, user-centred design, and digital learning environments.	Educational implementation strategies at school level remain unexplored.

8	Hiran et al. (2023)	AI and knowledge engineering	Edited volume	AI supports intelligent decision-making, IoT integration, business intelligence, and automation across sectors.	Limited discussion of AI applications in school education and STEM classrooms.
9	Das et al. (2022)	Machine learning for analysing student feedback	Machine learning and sentiment analysis	AI successfully evaluates teaching effectiveness through sentiment analysis and feedback analytics.	Did not investigate AI-supported classroom instruction or STEM learning outcomes.
10	Ashwini et al. (2022)	NLP-enabled chatbot for rural healthcare	AI application development	AI chatbots improve accessibility and remote communication using Natural Language Processing.	Educational chatbot applications for STEM teaching remain insufficiently explored.
11	Majumder et al. (2021)	AI for mental health prediction	Machine learning analysis	AI effectively predicts stress and depression using behavioural datasets.	Does not investigate AI applications in teaching-learning processes.
12	Singh et al. (2021)	Artificial Neural Network for transportation prediction	ANN modelling	Neural networks accurately predicted transportation costs using optimized algorithms.	Focuses on industrial applications rather than educational innovation.
13	Khan et al. (2020)	AI during COVID-19 pandemic	Review study	AI supported healthcare, surveillance, education continuity, and pandemic management.	Limited discussion of long-term AI integration into school education.
14	Mishra & Chakraborty (2019)	Smart cities using AI and IoT	Conceptual framework	AI, IoT, and cloud computing improve public services, governance, and sustainable development.	Educational implications of smart technologies remain underexplored.
15	Kouziokas (2015)	GIS-based learning environment	Information system development	GIS-based interactive learning improved spatial reasoning and student-centred learning.	AI-enabled STEM learning environments were not addressed due to technological limitations at that time.

3. Research Gap

The review indicates that existing studies have extensively examined Artificial Intelligence in digital governance, higher education, adaptive learning, robotics, engineering education, machine learning, and intelligent educational systems. However, there remains a significant lack of empirical research focusing on AI-enabled STEM education at the school level in Tripura, particularly concerning teacher readiness, digital infrastructure, rural–tribal educational contexts, implementation challenges, policy support, and strategic frameworks for future-ready learning. The present study addresses this gap by proposing a comprehensive framework for integrating Artificial Intelligence into STEM education in Tripura while considering local educational needs and contextual challenges.

Research Design: The study will adopt a quantitative, descriptive, and explanatory research design to examine how Artificial Intelligence (AI) can enhance STEM education in Tripura. The descriptive component will assess respondents' perceptions of AI awareness, infrastructure, teaching practices, readiness, opportunities, challenges, and institutional support. The explanatory component will test the direct influence of these factors on Future-Ready Learning (FRL) through Structural Equation Modelling (SEM).

Population and Sample: The study population will include school teachers and senior secondary students associated with STEM education in selected government and private schools of Tripura. A total sample of 450 respondents will be selected using a stratified random sampling technique. Schools will be selected from urban, rural, and tribal-dominated areas to ensure representation of different educational contexts.

Data Collection Method: Primary data will be collected through a structured questionnaire using a five-point Likert scale:

Response	Score
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

The questionnaire will include 51 initial items across nine constructs. After validity and reliability assessment, 31 items will be retained for Confirmatory Factor Analysis and SEM.

Study Variables

Variable Type	Constructs
Independent variables	AI Awareness (AIA), AI Infrastructure Readiness (AIR), AI Teaching and Learning (AITL), Teacher Readiness (TR), Opportunities of AI (OAI), Student Readiness (SR), Challenges in AI Adoption (CAI), Policy and Institutional Support (PIS)
Dependent variable	Future-Ready Learning (FRL)

4. Proposed Structural Model

The structural relationship will be tested through the following equation:

Where represents Future-Ready Learning; to are path coefficients; and is the error term.

Data Analysis Methods

Stage	Method	Purpose
Data screening	Missing-value check, outlier assessment, normality test	To ensure accuracy and suitability of data for analysis
Descriptive analysis	Frequency, percentage, mean, and standard deviation	To describe respondent characteristics and perceptions
Reliability test	Cronbach's alpha	To assess internal consistency of questionnaire items; $\alpha \geq 0.70$ will be considered acceptable
Exploratory Factor Analysis	KMO and Bartlett's test; factor extraction	To identify the underlying factor structure
Confirmatory Factor Analysis	Standardized factor loadings, CR, AVE, MSV	To establish convergent and discriminant validity
Structural Equation Modelling	Regression weights, critical ratio, and p-value	To test the hypothesized effects on FRL
Model-fit evaluation	CMIN/DF, RMR, GFI, AGFI, PGFI	To assess the overall adequacy of the SEM model

5. Hypothesis Testing

A hypothesis will be accepted when the path coefficient is statistically significant at $p < 0.05$. Positive estimates will indicate a favourable effect on Future-Ready Learning, whereas negative estimates will indicate an adverse effect. The model will be considered acceptable when CMIN/DF is below 3.00, RMR is below 0.08, GFI is above 0.90, AGFI is above 0.85, and PGFI is above 0.50.

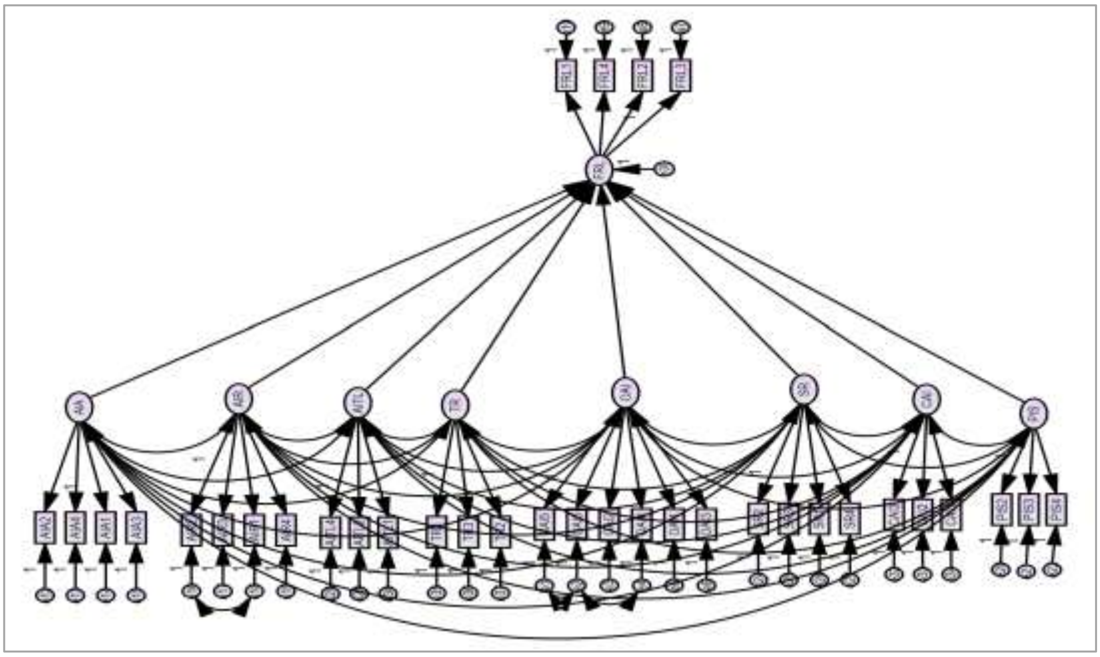

Figure: Structural Equation Model of AI-Enabled STEM Education Factors Influencing Future-Ready Learning in Tripura

Source: Author's compilation based on primary survey data (N = 450) and AMOS output.

The Structural Equation Modelling results show that the proposed model provides an acceptable to good fit to the data collected from 450 respondents. The model-fit values were satisfactory: CMIN/DF = 1.596, RMR = 0.032, GFI = 0.906, AGFI = 0.886, and PGFI = 0.743. These results confirm that the model is suitable for examining factors influencing Future-Ready Learning in STEM education in Tripura. Among the eight proposed predictors, three had significant positive effects on Future-Ready Learning. Opportunities of AI in STEM Education was the strongest predictor ($\beta = 0.382$, C.R. = 9.176, $p < 0.001$). This indicates that respondents believe AI-supported tools such as virtual laboratories, intelligent tutoring, simulations, coding platforms, robotics, and personalized learning can substantially improve future-oriented STEM competencies.

AI Infrastructure Readiness also had a strong and significant positive effect on Future-Ready Learning ($\beta = 0.362$, C.R. = 3.889, $p < 0.001$). Availability of reliable internet connectivity, digital devices, electricity, software, smart classrooms, and technical support is therefore essential for effective AI integration in Tripura's schools. Policy and Institutional Support showed a significant positive effect on Future-Ready Learning ($\beta = 0.318$, C.R. = 2.496, $p = 0.013$). This finding highlights the importance of government initiatives, school-level planning, financial assistance, curriculum support, professional development, and administrative commitment. However, AI Awareness ($\beta = -0.049$, $p = 0.240$), AI Teaching and Learning ($\beta = -0.028$, $p = 0.682$), Teacher Readiness ($\beta = 0.066$, $p = 0.220$), Student Readiness ($\beta = 0.013$, $p = 0.656$), and Challenges in AI Adoption ($\beta = -0.035$, $p = 0.581$) did not have statistically significant direct effects on Future-Ready Learning. Overall, the findings support H2, H5, and H8 only. The results establish that AI opportunities, infrastructure readiness, and policy–institutional support are the principal drivers of future-ready STEM learning in Tripura

6. Conclusion

The study concludes that AI can become an important enabler of future-ready STEM education in Tripura when its implementation is supported by adequate infrastructure, meaningful educational opportunities, and strong institutional commitment. The SEM findings confirm that Opportunities of AI, AI Infrastructure Readiness, and Policy and Institutional Support are the three significant drivers of Future-Ready Learning. Among these factors, Opportunities of AI emerged as the strongest predictor, showing that stakeholders recognize the value of AI-based simulations, virtual laboratories, robotics, coding platforms, intelligent tutoring, and personalized learning for strengthening STEM competencies. AI Infrastructure Readiness was also found to have a significant positive effect. This highlights the need for reliable internet connectivity, uninterrupted electricity, adequate digital devices, software access, smart classrooms, and technical maintenance particularly in rural and tribal-dominated schools. Policy and Institutional Support further demonstrated a positive influence, indicating that school leadership, government funding, curriculum integration, teacher-development programmes, and monitoring mechanisms are vital for successful AI adoption. Although AI awareness, teaching practices, teacher readiness, student readiness, and adoption challenges were not significant direct predictors, they should not be ignored. Their influence may be indirect and dependent on the availability of infrastructure and policy support. Therefore, Tripura should adopt a phased and inclusive AI–STEM strategy that prioritizes digital equity, teacher capacity-building, local-language learning resources, ethical AI use, student-data protection, and partnerships with technology institutions. Such an approach can reduce educational disparities and prepare learners for the digital knowledge economy.

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