Vol 8, Issue 1, 2025 **Impact Factor: 8.535** DOI: https://doi.org/10.31426/ijamsr.2025.8.1.8020

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

Artificial Intelligence in STEM Education in Tripura: An exploration towards the Opportunities, Challenges, and a Strategic Framework for Future-Ready Learning

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ABSTRACT

Artificial Intelligence (AI) is increasingly transforming educational practices by enabling personalized learning, intelligent assessment, adaptive instruction, and technology-supported teaching. In the context of STEM education in Tripura, AI offers significant opportunities to improve learning quality, student engagement, conceptual understanding, and access to educational resources. AI-enabled tools such as intelligent tutoring systems, virtual laboratories, adaptive learning platforms, predictive analytics, and automated assessment systems can support students with diverse learning needs and help teachers deliver more effective instruction. Such technologies may be particularly valuable in rural and remote areas where access to specialized STEM teachers and advanced laboratory facilities remains limited. However, the integration of AI also involves several challenges, including inadequate digital infrastructure, limited internet connectivity, unequal access to devices, insufficient teacher training, financial constraints, data privacy concerns, algorithmic bias, and ethical issues. Therefore, a comprehensive strategic framework is required to ensure responsible and inclusive AI adoption in STEM education. The study emphasizes infrastructure development, teacher capacity building, curriculum integration, equitable access, ethical governance, and continuous evaluation as essential measures for creating a future-ready STEM education system in Tripura.

Keywords: *Artificial Intelligence, STEM Education, Tripura, Future-Ready Learning.*

1. INTRODUCTION

Artificial Intelligence (AI) has emerged as a transformative force in education, offering new possibilities for improving teaching, learning, assessment, and student engagement. In Science, Technology, Engineering, and Mathematics (STEM) education, AI can support personalized learning, intelligent tutoring, virtual laboratories, automated feedback, data-driven assessment, and adaptive instructional strategies. For a geographically diverse state such as Tripura, the integration of AI into STEM education [1] holds considerable potential for reducing learning gaps and expanding access to quality educational resources. Students in rural and remote areas can particularly benefit from AI-enabled digital platforms, multilingual learning tools, simulations, and interactive content that may overcome limitations related to infrastructure and specialist teachers. However, effective implementation also presents significant challenges, including inadequate digital connectivity, limited availability of devices, insufficient teacher training, data privacy concerns, unequal digital literacy, and financial constraints. These issues require careful policy planning and institutional support. Developing a strategic framework for AI-supported STEM education [2] in Tripura is

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therefore essential for ensuring inclusive, ethical, and sustainable adoption. Such a framework should emphasize infrastructure development, teacher capacity building, curriculum integration, responsible AI use, and equitable access, thereby preparing learners with the knowledge, skills, and competencies required for future education and employment.

1.1 Background and Emerging Role of Artificial Intelligence in STEM Education

Artificial Intelligence (AI) [3] has rapidly become an important component of modern educational systems by transforming traditional approaches to teaching, learning, assessment, and academic management. In STEM education, which includes Science, Technology, Engineering, and Mathematics, AI provides innovative tools that can make learning more interactive, personalized, and outcome-oriented. AI-based applications such as intelligent tutoring systems, adaptive learning platforms, virtual laboratories, educational chatbots, automated assessment tools, and predictive analytics enable students to learn according to their individual abilities, pace, and learning requirements [4]. These technologies also assist teachers in identifying learning difficulties, monitoring student progress, and providing timely academic support.

The growing importance of AI in STEM education is closely associated with the increasing demand for digital literacy, computational thinking, problem-solving, creativity, and technological skills required in the twenty-first-century workforce [5]. AI-supported simulations and virtual experiments can simplify complex scientific and mathematical concepts and provide practical learning experiences even where physical laboratory facilities are limited. Furthermore, AI can support inclusive education through multilingual content, accessibility tools, and customized learning resources. As educational institutions increasingly adopt digital technologies, AI is emerging not merely as a supporting tool but as an important mechanism for strengthening STEM learning, improving educational quality, and preparing students for technology-driven higher education and future employment.

1.2 Need and Significance of AI-Enabled STEM Education in Tripura

The need for AI-enabled STEM education [6] in Tripura has become increasingly significant in the context of rapid technological development, changing employment patterns, and the growing importance of digital competencies [7]. As a state with a substantial rural and geographically dispersed population, Tripura faces challenges related to unequal access to advanced educational resources, shortage of specialized STEM teachers in some areas, limited laboratory facilities, and variations in digital infrastructure. Artificial Intelligence can help address some of these gaps by providing personalized learning support, virtual laboratories, adaptive educational content, automated feedback, and digital tutoring systems that can be accessed beyond conventional classroom settings.

The significance of AI-enabled STEM education also lies in its ability to strengthen critical thinking, problem-solving, computational skills, innovation, and scientific reasoning among students. AI-based platforms can assist teachers in identifying individual learning difficulties and designing suitable interventions based on student performance. In Tripura, such technologies may also support multilingual and context-sensitive learning, making STEM subjects [8] more accessible to students

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from diverse social and linguistic backgrounds. Moreover, the integration of AI can improve students' preparedness for higher education, emerging careers, and technology-driven industries. Therefore, promoting AI-enabled STEM education [9] in Tripura is important for improving educational quality, reducing regional learning disparities, and developing a future-ready workforce capable of participating effectively in the digital economy [10].

2. RELATED REVIEW

Murdan (2024) explored the transformative potential of artificial intelligence (AI) in enhancing STEM (Science, Technology, Engineering, and Mathematics) education for slow learners. The study highlighted that AI-driven tools had provided personalized and adaptive learning experiences according to the individual learning requirements of students. It was reported that the integration of advanced technologies, including adaptive learning systems, virtual and augmented reality (VR/AR), natural language processing (NLP), and predictive analytics, had significantly improved learning outcomes, student engagement, and knowledge retention among slow learners. The study further examined the role of educational theories, such as differentiated instruction and constructivist learning approaches, in guiding the effective application of AI technologies in educational environments. Through various case studies, the research demonstrated that AI-based educational tools had been successfully implemented across different learning settings and had effectively supported students with diverse learning abilities. The findings also emphasized the challenges associated with AI implementation, including technological accessibility, ethical concerns, pedagogical limitations, and infrastructure requirements. The study concluded that the development of strong policy frameworks, equal access to digital technologies, continuous professional training for educators, and sustained research efforts had been essential for maximizing the benefits of AI in STEM education and creating inclusive learning environments for slow learners.

Abisoye (2023) investigated the need for a dynamic approach to curriculum development in response to the rapid evolution of science, technology, engineering, and mathematics (STEM) industries. The study highlighted that traditional curriculum frameworks were often unable to adapt quickly to changing workforce requirements, which resulted in skill gaps between graduates and industry expectations. The research explored the development of a conceptual framework for artificial intelligence-driven curriculum adaptation by integrating advanced technologies such as machine learning, natural language processing, and data analytics to improve educational responsiveness. The study examined the theoretical foundations of STEM curriculum evolution, AI applications in education, and learning theories supporting adaptive teaching approaches. A structured framework was proposed that included key components, technological enablers, data-driven decision-making mechanisms, and approaches for incorporating real-time industry feedback into curriculum design. The study also identified several challenges associated with AI-based curriculum adaptation, including limited data availability, ethical concerns, resistance among educators, and financial limitations. Furthermore, the research emphasized the importance of supportive regulatory frameworks, modular course structures, and collaboration among educational institutions, policymakers, and industry stakeholders. The study concluded that AI-driven curriculum adaptation could enhance the scalability and relevance of STEM education; however, issues related to data bias,

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infrastructure limitations, and inclusive AI governance required further attention. Future research directions were suggested to focus on improving AI capabilities, conducting long-term impact assessments, and promoting interdisciplinary collaborations for equitable implementation of AI-enabled educational models.

Ouyang et al., (2023) investigated the application of artificial intelligence (AI)-driven educational assessment in STEM education through a systematic review approach. The authors highlighted that AI had been increasingly adopted in STEM education to enhance assessment processes by enabling automated evaluation of students' learning outcomes and reducing instructors' workload. The study identified that limited review-based research had been conducted to comprehensively examine the role of AI-driven assessment within the STEM education domain. Therefore, the researchers analyzed 17 empirical studies published between January 2011 and April 2023 to explore the functions, algorithms, and impacts of AI applications in STEM educational assessment. The findings revealed that AI-based assessment systems had primarily been utilized for academic performance assessment, learning status evaluation, and instructional quality assessment. The study further reported that various algorithms, including traditional approaches such as natural language processing and machine learning, along with advanced techniques such as deep learning and neural fuzzy systems, had been implemented for STEM assessment applications. Additionally, the authors demonstrated that AI-driven assessment had contributed significantly to improving educational effectiveness and technological advancement. Based on these findings, the study suggested several educational and technological implications for future research and practical implementation of AI-based assessment systems in STEM education.

Akhmadieva et al. (2023) conducted a descriptive bibliometric analysis of research works related to Artificial Intelligence (AI) in science education to examine the development status and research trends in this emerging field. The study aimed to provide bibliometric insights into publications on AI in science education indexed in the Scopus database from 2002 to May 2023. The collected research articles were evaluated through descriptive bibliometric analysis based on seven major categories, including annual publication and citation trends, countries contributing the highest number of publications, productive authors, leading affiliations, funding organizations, publication sources, and subject areas. The findings revealed that the majority of publications had been produced between 2016 and 2022, indicating a significant growth of interest in AI applications within science education during this period. The United States, the United Kingdom, and China had been identified as the leading contributors, with the United States recording the highest number of publications. The citation analysis had shown a continuous increase in scholarly impact, reaching the highest citation count in 2022 with 178 citations. Salles, P. had been recognized as the most productive author, contributing four publications in the field. Furthermore, Carnegie Mellon University, the University of Memphis, and the University of Southern California had emerged as prominent research affiliations. The National Science Foundation had been reported as the leading funding institution supporting AI-based science education research. The study had also highlighted that *Proceedings Frontiers in Education Conference (FIE)* had been the most significant publication source. The distribution of research by subject area had demonstrated major contributions from computer science, social sciences, science education, and technology and engineering education domains. The study had provided a comprehensive global perspective and identified future research directions for advancing AI integration in science education.

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Salas-Pilco et al., (2022) investigated the role of artificial intelligence (AI) and emerging technologies in promoting inclusive education, particularly among minority students across diverse sociocultural contexts. The study had examined the potential of AI-based technologies to transform educational practices and had conducted a systematic review to analyze their benefits, challenges, and implications for inclusive learning environments. The findings had revealed that AI and new technologies had contributed to improved student academic performance, increased interest in STEM/STEAM education, enhanced student engagement, and provided several other educational benefits. However, the study had also identified various challenges associated with the implementation of AI-driven educational technologies, including technological limitations, pedagogical issues, dataset constraints, reduced user satisfaction, and cultural differences. The authors had proposed possible solutions at technological, pedagogical, and sociocultural levels to overcome these barriers and had emphasized the importance of addressing students' diverse backgrounds while implementing AI-based educational systems. The study had concluded that effective integration of AI and emerging technologies could support sociocultural inclusiveness in education and had provided valuable insights for teachers, practitioners, and policymakers in developing equitable and technology-enabled learning environments.

Zafari et al., (2022) investigated the integration of Artificial Intelligence (AI) in K–12 education and highlighted its growing significance in addressing emerging educational challenges. The study stated that education had continuously evolved in terms of teaching methods, learning content, concepts, and instructional models, and AI had emerged as a promising technology for improving educational practices. A systematic literature review was conducted on research articles and conference papers published between 2011 and 2021, collected from the Web of Science and Scopus databases. Initially, 2075 documents were identified, and after applying inclusion and exclusion criteria, 210 studies were selected for detailed analysis. The findings revealed that AI applications had been primarily utilized in areas such as student performance evaluation, teaching support, educational selection processes, behavioural analysis, and other educational tasks. Among various AI approaches, Machine Learning (ML) and Intelligent Tutoring Systems (ITS) had been identified as the most commonly applied techniques. The study further reported that AI-based educational applications had been more frequently implemented at the high school level, with STEM education receiving significant attention. The researchers concluded that AI had demonstrated substantial potential in transforming K–12 education by supporting personalized learning, improving teaching effectiveness, and enhancing educational decision-making. The study had also suggested that future research should explore additional databases, inaccessible studies, pedagogical frameworks, and AI development tools to further understand the role of AI in educational systems.

Chiu et al. (2021) developed and evaluated the Chinese University of Hong Kong (CUHK)-Jockey Club AI for the Future Project (AI4Future), which had introduced the first pre-tertiary Artificial Intelligence (AI) curriculum framework at the secondary school level in Hong Kong. The study had contributed to the field of AI education by presenting a novel curriculum model and examining its effectiveness in enhancing students' perceptions and learning experiences related to AI. The research had investigated whether the developed curriculum significantly improved students' perceived competence, attitudes, and motivation towards AI learning, along with assessing the benefits of the

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co-creation approach for curriculum implementation. The AI4Future project had involved collaboration among multiple stakeholders, including CUHK's Faculty of Engineering and Faculty of Education, secondary schools, the Hong Kong government, and AI industry partners. A team of 14 professors had collaborated with 17 school principals and teachers from six secondary schools to co-create and implement the curriculum. The study had adopted a mixed-method research approach involving 335 students and eight teachers from participating secondary schools. Quantitative data had been collected through pre- and post-intervention questionnaires, while qualitative data had been obtained through teachers' reflections on the curriculum development and implementation process. Statistical analyses, including paired t-tests and ANCOVA, along with thematic analysis, had been applied to evaluate the outcomes. The findings had revealed that the AI curriculum had significantly improved students' perceived competence and developed more positive attitudes towards AI learning. Furthermore, the co-creation process had strengthened teachers' AI knowledge, enhanced their confidence, and promoted greater autonomy in integrating AI concepts into classroom teaching. The study had demonstrated that collaborative curriculum development approaches could effectively support AI education adoption at the secondary school level.

Yousuf & Wahid (2021) had examined the significant role of education in the development of individuals and society. The study had explored the emerging applications of Artificial Intelligence (AI) in the educational sector and had identified new possibilities for innovation in educational technologies. The authors had highlighted that Artificial Intelligence had become an essential component of modern education systems and had provided competitive advantages through advanced learning solutions. The research had reviewed various AI-based educational applications, existing tools, market trends, research developments, opportunities, challenges, and limitations associated with AI integration in education. The study had particularly focused on applications such as intelligent tutoring systems, classroom monitoring, recommendation systems, sentiment analysis, student retention analysis, dropout prediction, grading, and evaluation mechanisms. For conducting the review, the researchers had analysed several studies related to educational data mining (EDM), big data in education, and learning analytics. The findings had provided a comprehensive understanding of AI-based educational platforms and tools developed through previous research. Furthermore, the study had identified critical limitations, implementation challenges, and future opportunities for enhancing AI-driven e-learning environments. The research had established a foundation for future investigations aimed at improving the effectiveness, accessibility, and intelligence of educational systems through Artificial Intelligence.

Luan et al., (2020) discussed the emerging challenges and future directions associated with the application of big data and Artificial Intelligence (AI) in educational research, policy-making, and industry. The study highlighted that the adoption of big data and AI technologies in education had made significant progress in recent years and represented a new trend in advanced educational research. The authors reported that the integration of data collection capabilities within educational technologies and computational analysis techniques had enabled the effective utilization of large-scale educational data. They observed that research in this field had gradually moved beyond experimental demonstrations toward practical implementation across various educational domains.

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The study identified major research trends in big data and AI-based education, including automated assessment, personalized learning, and precision education. It emphasized that model-driven data analytics approaches would play an important role in guiding the development, interpretation, and validation of intelligent algorithms. However, the authors suggested that findings generated through educational analytics should have been interpreted carefully due to potential limitations and contextual factors. At the policy level, the study recommended that governments should have focused on promoting lifelong learning, strengthening teacher training programs, and ensuring the protection of personal data. Furthermore, the authors highlighted the importance of establishing collaborative relationships between academia and industry to enhance technological development in education. The study concluded that educational technologies should have been supported by strong theoretical frameworks and empirical validation. Finally, the authors advocated a balanced interaction between technological advancement and human-centered educational practices to ensure that big data and AI innovations could have been effectively utilized for improving teaching methodologies and learning outcomes.

Dai et al. (2020) had developed and validated an instrument for measuring students' readiness to learn about Artificial Intelligence (AI). The researchers had designed a survey questionnaire that was administered among primary students in a school district in Beijing after the implementation of an AI course. The collected data and analytical outcomes had provided significant insights into students' self-reported perceptions regarding AI readiness and had helped identify the factors influencing this parameter. The findings had revealed that AI literacy had not directly predicted students' AI readiness; however, its impact had been mediated through students' confidence and their perception of the relevance of AI. The study had further indicated that students' AI readiness had not been significantly affected by reduced AI-related anxiety or increased AI literacy alone. Male students had reported higher levels of confidence, perceived relevance, and readiness toward AI compared with female students. The analysis of open-ended responses had demonstrated that students had shown positive attitudes and enthusiasm toward learning AI, considering it a powerful and beneficial technology. These qualitative responses had supported the quantitative findings of the study. The validated instrument had been considered useful for teachers to assess and monitor students' AI learning progress and to improve AI curriculum design and teaching effectiveness.

3. TABULAR REVIEW

Author(s) & Year	Focus of the Study	Method / Sample	Major Findings	Research Relevance
Murdan (2024)	AI-supported STEM education for slow learners	Review and case-study-based examination	Adaptive learning, VR/AR, NLP and predictive analytics improved engagement, retention, and learning outcomes. Accessibility, ethics, pedagogy and infrastructure remained challenges.	Emphasized inclusive AI integration and the need for strong infrastructure and teacher training.

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Abisoye (2023)	AI-driven adaptation of STEM curriculum to changing industry requirements	Conceptual framework	ML, NLP and data analytics could support dynamic curriculum design and reduce skills gaps, while data, financial, ethical and governance issues remained.	Highlighted the importance of AI-responsive curriculum development for future-ready skills.
Ouyang et al. (2023)	AI-driven educational assessment in STEM	Systematic review of 17 empirical studies, 2011–2023	AI was used for academic assessment, learning-status evaluation and instructional-quality assessment, reducing instructors' workload.	Established the role of AI in improving STEM assessment and feedback systems.
Akhmadieva et al. (2023)	Global research trends in AI and science education	Bibliometric study of Scopus publications, 2002–2023	Research increased substantially after 2016, with the USA, UK and China emerging as leading contributors.	Demonstrated growing international interest in AI-enabled science and STEM education.
Salas-Pilco et al. (2022)	AI and emerging technologies for inclusive education among minority students	Systematic review	AI improved academic performance, STEM/STEAM interest and engagement, but technological, pedagogical, cultural and dataset-related challenges remained.	Relevant for developing equitable AI-based education for socially and culturally diverse learners.
Zafari et al. (2022)	AI applications in K–12 education	Systematic review of 210 studies from 2011–2021	ML and intelligent tutoring systems were frequently used for performance evaluation, teaching support and behavioural analysis, particularly in STEM.	Demonstrated the strong potential of AI for personalized K–12 STEM education.
Chiu et al. (2021)	Development and evaluation of an AI curriculum for secondary schools	Mixed-method study; 335 students and 8 teachers	AI curriculum improved students' competence and attitudes, while co-creation strengthened teachers' AI knowledge, confidence and autonomy.	Showed the importance of collaborative curriculum design and teacher capacity building.
Yousuf & Wahid (2021)	Applications, opportunities and challenges of AI in education	Review of educational data mining, big data and learning analytics studies	AI supported intelligent tutoring, monitoring, recommendation, grading, dropout prediction and evaluation.	Provided a broad foundation for understanding AI-enabled teaching and learning systems.

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Luan et al. (2020)	Big data and AI in educational research, policy and industry	Conceptual/review study	Major developments included automated assessment, personalized learning and precision education; teacher training, privacy and academia-industry collaboration were emphasized.	Highlighted policy, teacher development, privacy and human-centred approaches necessary for AI adoption.
Dai et al. (2020)	Students' readiness to learn Artificial Intelligence	Survey of primary-school students in Beijing	Confidence and perceived relevance mediated AI readiness, while AI literacy alone did not directly predict readiness. Gender differences were also observed.	Demonstrated the importance of learner confidence, attitudes and readiness in implementing AI education.

4. CONCLUSION

Artificial Intelligence has the potential to significantly strengthen STEM education in Tripura by making learning more personalized, interactive, inclusive, and future-oriented. AI-enabled tools such as adaptive learning platforms, intelligent tutoring systems, virtual laboratories, automated assessment, and predictive analytics can improve conceptual understanding, student engagement, problem-solving ability, and access to quality learning resources. These technologies may be especially useful for learners in rural and remote areas where specialized teachers, laboratory facilities, and advanced educational resources are limited. However, effective integration of AI also requires attention to major challenges, including inadequate digital infrastructure, limited internet connectivity, unequal access to devices, insufficient teacher training, financial constraints, data privacy concerns, algorithmic bias, and ethical issues. Therefore, AI adoption in STEM education should be supported by a clear and inclusive strategic framework. Such a framework should emphasize infrastructure development, continuous professional training for teachers, curriculum integration, responsible data governance, equitable access, institutional collaboration, and regular evaluation of learning outcomes. With careful planning and responsible implementation, AI can help Tripura improve the quality and accessibility of STEM education and prepare students with scientific, digital, analytical, and technological competencies required for higher education, innovation, and emerging employment opportunities within an increasingly competitive, technology-driven national and global economy.

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