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Artificial Intelligence Based Mathematical Education in Sustainable Development for Academics

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Abstract
Artificial intelligence (AI) used for education at different courses, the study of comparison and view for implementing sustainable awareness using AI is targeted in this article. The concepts of NEP2020 intertwined with sustainability motive for mathematics education is the key area of investigation. It includes adaptive and personalized learning systems, intelligent tutoring and conceptual understanding, AI supported assessment and learning analytics. We focus on the contribution of AI in achieving sustainable goals such as advancing inclusive and quality education, skill development and scalability in the education system, challenges and ethical dimensions. A review of NEP2020 for sustainability is included for the completeness of the concepts. Observations are tabulated and analyzed using the present research carried in this direction. A detailed summary is presented for addressing the specific research questions such as what are the sustainability goals in education in general, what are the mathematical educational inclusions for the sustainability goals using machine learning, what are the researches done during the period of 2020 to 2025 to achieve SDG4. The paper reviews the recent literature and indicates the research gaps to be addressed. Data driven academic planning is to be focused for the valid implementation of sustainability goals in education.
Keywords: *Mathematical education, artificial intelligence, AI supported sustainability applications, NEP2020, SDG4*

1. Introduction

Sustainability is fundamentally about how societies make choices that affect both present and future generations. These choices influence environmental protection, economic stability, and social well-being, and they are increasingly shaped by data, models, and predictions. Universities therefore have an important role in preparing students to understand complex systems and to participate responsibly in shaping a sustainable future. In higher education, learning for sustainability emphasizes understanding connections—between disciplines, between theory and practice, and between individual actions and global outcomes. Rather than treating sustainability as a separate topic, universities are encouraged to embed it within existing fields of study, helping students recognize how their academic knowledge can be applied to real challenges such as climate change, resource management, and economic uncertainty. Mathematics is a key contributor to this effort. It provides ways to describe patterns, measure change, manage uncertainty, and test possible outcomes. At the university level, mathematical subjects such as calculus, probability, statistics, linear algebra, and mathematical modeling support the analysis of real-world systems, from environmental processes to technological and economic models. Through mathematics, students gain tools to move beyond intuition and base decisions on evidence and logical reasoning. To align mathematics education with sustainability goals, teaching should balance theoretical understanding with meaningful application. When students explore mathematical concepts through contexts related to sustainability such as analyzing data on energy consumption or modeling population trends they begin to see mathematics as a practical and relevant discipline. This approach strengthens both conceptual learning and the ability to apply mathematics responsibly. The broader aim of university mathematics education, therefore, extends beyond mastering techniques or

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formulas. It includes developing quantitative literacy, critical thinking, and an awareness of how mathematical tools influence real-world decisions. By integrating sustainability perspectives into mathematics courses, universities can support the development of graduates who are not only mathematically competent but also prepared to contribute thoughtfully to a more sustainable society. Mathematics is a fundamental component of engineering education, serving as the basis for modeling, analysis, and problem-solving across all engineering disciplines. Despite its importance, engineering mathematics is often perceived as challenging by students due to its abstract nature and traditional teacher-centered instructional approaches. These challenges have prompted educators to explore innovative teaching strategies that can support diverse learners more effectively Figure 1 shows the major three pillars of sustainability goals namely mathematical foundation, critical thinking and sustainability goals.

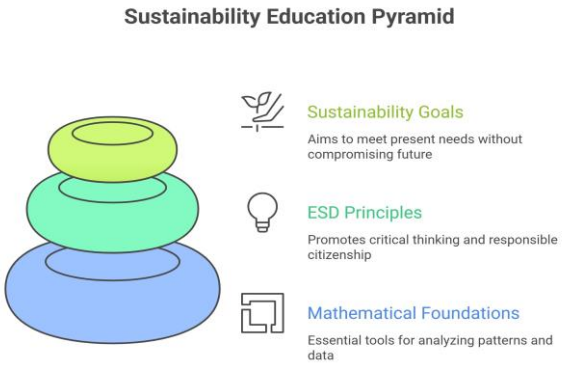

Figure 1 Education Pyramid

The emergence of Artificial Intelligence (AI) in education has created new opportunities to enhance learning outcomes by offering personalized instruction, adaptive content delivery, and continuous feedback. In India, the National Education Policy (NEP) 2020 highlights the strategic use of digital technologies, including AI, to improve educational quality and accessibility. The policy also aligns national educational reforms with the United Nations Sustainable Development Goals (SDGs), particularly the goal of ensuring inclusive and equitable quality education. This review examines existing research on AI-based learning in engineering mathematics and discusses its relevance to sustainable development and NEP 2020 objectives. NEP 2020 introduces a comprehensive vision for transforming higher education by emphasizing flexibility, interdisciplinary learning, and technology integration. The policy encourages the use of AI to support personalized learning, improve assessment mechanisms, and enhance institutional effectiveness. Initiatives such as the National Educational Technology Forum (NETF) and proposed Centers of Excellence in Artificial Intelligence demonstrate the government's commitment to embedding emerging technologies into the educational ecosystem (Government of India, 2020).

Within engineering education, NEP 2020 advocates outcome-based learning, critical thinking, and problem-oriented pedagogy. AI-based educational systems align naturally with these principles by enabling learner-specific pathways and providing timely diagnostic feedback. Moreover, the policy underscores the importance of digital inclusion to ensure that technological advancements benefit learners across socioeconomic backgrounds.

In section 2 discussion of AI in engineering mathematics education is included. Section 3 contributions of AI based learning to sustainable development goals is focused, which includes the three major research questions addressed in this paper followed by the conclusion. The research gaps and analyses are summarized in the conclusion which would help the researchers to address the challenges faced during the implementation of sustainable goals in education.

2. Applications of AI in Engineering Mathematics Education

AI can greatly support the learning of engineering mathematics. By using AI-powered tools, students can understand concepts more easily, solve complex problems more efficiently, and receive personalized guidance. These tools make learning more interactive, provide instant feedback, and help students practice at their own pace. Overall, integrating AI into the learning process improves understanding, increases accuracy, and enhances the

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overall effectiveness of engineering mathematics education.

2.1 Adaptive and Personalized Learning Systems

Teaching of mathematics has been completely upgraded by use of artificial intelligence. Through artificial intelligence, adaptive learning platforms has been engineered to the needs of individual students. By dynamically adjusting content difficulty, identifying specific knowledge gaps, creating personalized learning pathways, and providing immediate feedback based on student performance analysis, these advanced systems successfully convert traditional standardized instruction into responsive educational experiences that instantly adjust to each student's individual learning path [1]. Some Finnish upper comprehensive and secondary schools use AI adaptive learning tools in their mathematics curriculum. The Finnish EdTech company Claned has developed ML-based adaptive environments that track students' learning behavior—how they engage with content and where they spend more time—to provide customized support [2].

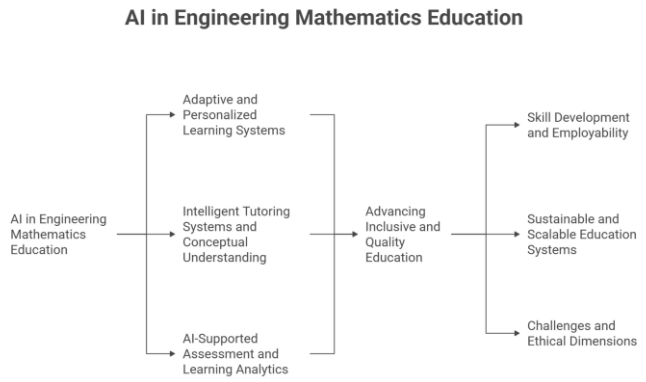

Figure 2 Flow of Research in AI for Education.

Figure 2 describes the overview of the flow of research done in AI for engineering mathematics from the inception of AI in education. Following are a few AI tools which are used for mathematical education. IXL: IXL is an online learning platform designed for students up to Grade 12, offering comprehensive practice resources across multiple subjects, including mathematics, English, science, and social studies. The platform provides structured skill-based exercises aligned with various national curricula, allowing users to customize content based on their country or educational standards. IXL offers free access to limited practice questions, while extended features and unlimited practice require a subscription. Its adaptive learning system provides immediate feedback and personalized recommendations, helping students strengthen their understanding and track their academic progress effectively.

Photo math: Photo math is an AI-based mathematics learning application that utilizes Optical Character Recognition (OCR) technology to scan and interpret both handwritten and printed mathematical expressions. After recognizing the problem, the tool generates step-by-step solutions along with detailed explanations to enhance conceptual understanding. It is particularly beneficial for elementary and secondary school students in strengthening foundational mathematical skills. Although Photo math offers valuable learning support, many of its advanced features are available through a paid subscription model. It also uses optical character recognition. We can scan and solve the questions. It recognizes handwritten or printed mathematical expressions and explains solution steps. This tool is useful for elementary school. It is a paid tool.

QANDA: QANDA is an AI-powered mathematics learning tool that functions similarly to a MathGPT system. It allows students to upload or scan images of mathematical problems, after which it provides detailed, step-by-step solutions along with clear explanations. The tool utilizes Optical Character Recognition (OCR) technology to accurately extract text and mathematical expressions from images. By combining OCR with AI-based problem-solving algorithms, QANDA helps students understand both the solution process and the underlying reasoning behind each step.

GeoGebra: GeoGebra, derived from the terms Geometry and Algebra, is an interactive mathematics software widely used for school-level education up to Grade 12. The platform provides dynamic and visually rich graph representations that enhance conceptual understanding through interactive

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exploration. Integrates multiple features, including a graphing calculator, geometry tools, a 3D calculator, a scientific calculator, and note-preparation capabilities. GeoGebra covers a broad range of topics in geometry, algebra, and related mathematical areas. One of its most distinctive features is that it is open-source and multilingual, making it accessible to a diverse global audience and supporting inclusive learning environments

Dream Box: Dream Box Math is an AI-driven adaptive learning platform designed primarily for students from kindergarten to Grade 8. It continuously analyzes student responses and adjusts lesson content, difficulty, and pace to provide personalized instruction. The platform supports conceptual understanding and skill development in mathematics while offering real-time progress reports for teachers and parents.

2.2 Intelligent Tutoring Systems and Conceptual Understanding

As students increasingly turned to online learning tools and digital assistance, a significant shift away from traditional face-to-face classroom instruction became evident. This trend has continued as AI-powered educational tools have made personalized, on-demand learning more accessible than ever. One of the AI based computer applications include Intelligent Tutoring System (ITS), which is a pedagogical computer program which imitates assistance to students as a human educator without the need of human interference. In the intelligent tutoring system, the student is personally guided according to their situation in that subject, and feedback is given to the student about what they have done [3]. According to [4] 11.62% of the reviewed documents use ITSs to explain a specific topic and provide instruction on the process of solving mathematical problems. Educators can also use ITS to promote participation, interaction and collaborative work along with improvement in learning. ITS also has its own limitations such as the sample size for the study is taken very small which might not give accurate results, connectivity issues, technical problems and so on. One of the major setbacks was that these systems were not specified according to the curriculum.

2.3 AI-Supported Assessment and Learning Analytics

Using AI tools in assessment offers significant advantages for tutors by reducing the time required for marking and providing students with immediate feedback. AI can provide feedback on grammar, spelling, and syntax by analyzing essays, reports, and other written assignments [5] The tools such as Gradescope (by Turnitin), Knewton Alta, Socrative, Century Tech, Cognii, Querium are some which helps educators for assessing handwritten responses / quizzes and give students instant feedback. An AI based learning platform 'Samagra plus AI' was developed by Kerala Infrastructure and Technology for Education (KITE) for schools in Kerala. This platform includes various modules such as chatbot systems, quizzes, English language games, a speech assistant and assessment mechanism. Figure 3 shows the detailed methodology used in

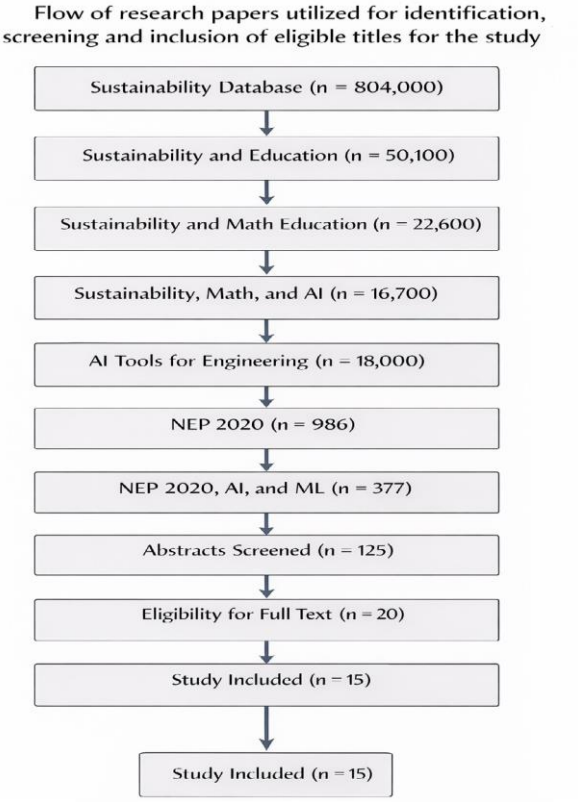

Figure 3 Flow Chart for the Methodology Used in Literature Review.

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3. Contribution of AI-Based Learning to Sustainable Development Goals

In the paper [6] it revealed that AI-powered discourse interventions support multiple SDG 4 targets including improving learning outcomes (Target 4.1), promoting equity and inclusion (Target 4.5), and strengthening teacher capacity through professional development (Target 4.c). Advancing Inclusive and Quality Education AI systems track learner progress in real time and tailor content to individual needs, improving understanding and performance across diverse learners. Studies highlight how AI enhances personalized learning paths and adaptive support in education.AI tools help students with diverse needs through features such as automated captioning and translation. These innovations directly contribute to inclusivity by reducing barriers to learning. It's interactive feedback and intelligent tutoring systems increase student engagement in learning.

Skill Development and Employability

AI platforms help students to develop both technical and soft skills and make them more employable. These include communication tools and coding assistants. AI is increasingly integrated into vocational curricula and higher education programs to simulate real-world tasks, offering students practical competence aligned with labor market needs. AI can analyze learner data to recommend career tracks and skill gaps, aligning education with workplace demands and emerging industries.

Sustainable and Scalable Education Systems

AI makes education more scalable by enabling distance learning and automated assessments. This allows institutions to serve larger learner populations. AI-powered systems optimize administrative workload like grading automation by freeing teacher time and reducing costs. Also, by analyzing institutional data AI can help reduce waste using paperless systems.

Challenges and Ethical Dimensions

SDG 4 addresses several fundamental challenges in the global education system, including limited access to schooling, unequal quality of education, and the need to promote lifelong learning opportunities for all. It recognizes that achieving universal, high-quality education requires comprehensive and systemic transformation in both developed and developing countries. Although significant progress has been made in recent years, millions of learners still lack access to quality education due to persistent barriers such as economic inequality, geographical isolation, disability, gender-based discrimination, and social disadvantage. These challenges highlight the urgent need for inclusive policies, equitable resource distribution, and innovative approaches to ensure that no learner is left behind. Around 260 million children remained unenrolled in school in 2018, nearly one-fifth of the world's population in that age range. Additionally, almost half of all children and adolescents globally do not fulfil the minimal requirements for reading and math ability [7]. Additionally, concerns were raised about a potential reduction in direct interaction between students and educators due to excessive reliance on AI-based systems. Human interaction remains essential for fostering emotional connection, mentorship, and holistic learning. Figure 4 depicts the alignment of various education driven applications with the corresponding NEP2020 objectives.

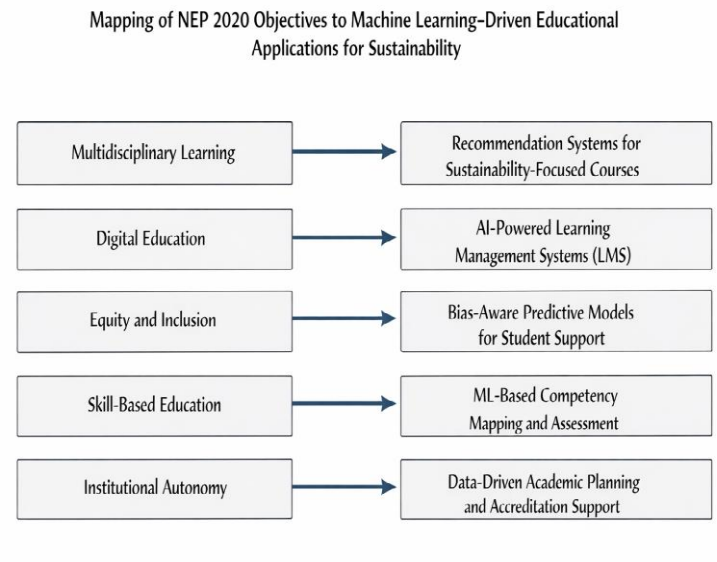

Figure 4 Mapping of Nep2020 with the Machine Learning Driven Educational Application for Sustainability.

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Research Questions Addressed

R1. What Are the Sustainability Goals in Education?

Sustainability goals include a total of 17 goals which includes Poverty and inequality, clean energy, climate action, clean water, education to name a few. The focus on SDG4 is about quality education. The study focuses on the recent advances in the years 2020 to 2025 and could analyse that a significant improvement in areas such as universal enrollment through Ajusted net enrollment rate (ANER) reached 96 % and there was a significant improvement of 30 % in higher education enrollment. Several schemes such as Sarva Siksha Abhiyan (SSA) and Right to Education (RTE) have contributed towards this move [8]. Financial gap and regional disparity have played a key role in the lack of sufficient growth of awareness.

R2 What are the Mathematical educational inclusions for the sustainability goals using ML?

Sustainable Development Goal (SDG) 4 focuses on ensuring inclusive, equitable and high-quality education while promoting lifelong learning opportunities for all. It seeks to guarantee that every child completes free, safe and good primary and secondary education by 2030. The goal also emphasizes equal access to affordable vocational training, the removal of gender and socioeconomic disparities in education, and the achievement of universal access to quality higher education. Machine Learning (ML) plays a significant role in achieving the objectives of SDG 4 by transforming how educational data is used to support learners. ML algorithms can analyse large volumes of student data—including attendance records, assignment scores, learning behavior, engagement patterns, and even responses to digital assessments—to identify trends that are not easily visible to teachers. By recognizing these hidden patterns, ML systems can accurately predict student performance, detect learning gaps, and identify those who may be at risk of falling behind. Such predictive insights enable educators to provide timely and personalized support. For example, ML-driven dashboards can highlight students who need extra help, recommend targeted learning resources, or suggest skill-building activities based on individual strengths and weaknesses. Moreover, ML models can adapt the difficulty level of tasks, ensuring that each student receives instruction suited to their pace and learning style. This reduces disparities in the classroom and promotes a more inclusive and equitable learning environment. In addition, machine learning supports long-term educational planning by helping institutions evaluate program effectiveness, optimize resource allocation, and improve curriculum design. Through data-driven decision-making, schools and colleges can ensure higher-quality education and better learning outcomes—directly contributing to the achievement of SDG 4.

Some of the organizations that have their vision of achieving these educational goals are listed below as highlighted in one of his blogs by Omdena.

- Labster: It has created virtual labs and science simulations for universities and high schools.
- Udemy: Online learning and teaching platform.
- AltSchool: Gives a platform to enable teachers to personalize the curriculum and track students' progress.
- Code academy: Offers courses and projects on various coding programming topics
- Praxilabs: Offers a virtual solution for science education that replicates real world experiments in the field of biology, chemistry and physics.
- TED-Ed: Offers interactive lessons and short videos by collaborating with various educators.

R3 What Research Is Being Done During 2020-2025 On the Topics of Mathematical Education in Relation to Contributions Towards A Sustainable Future?

As mentioned in the paper [9] teacher training programs can be modeled in such a way that education in mathematics is linked with sustainability. The teachers are trained so that they can explain to the students how mathematical knowledge is applied to sustainable development, to sustain in this evolving environment. Observations

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for machine learning algorithms for NEP2020 in the sense of sustainability goals Machine learning algorithms play a transformative role in advancing sustainable, inclusive, and technology-driven education under NEP 2020. Through supervised, unsupervised, reinforcement, and deep learning approaches, engineering-based educational systems can achieve improved learning outcomes, optimized resource utilization, and long-term sustainability. Strategic alignment of ML technologies with national education policies will be critical in shaping resilient and future-ready educational ecosystems. Major challenges include explainable AI in educational fields, giving structured low carbon machine learning models for sustainable campuses, including sustainability to the current engineering curriculum.

Conclusion

The integration of artificial intelligence (AI) tools in education has the potential to significantly enhance educational quality and support the achievement of the Sustainable Development Goals (SDGs), particularly SDG 4. This paper examines various applications of AI in teaching and learning, with a focus on how these technologies contribute to sustainable educational development. Different AI tools are identified and discussed, highlighting their role in improving instructional methods through innovative techniques such as visual representation and interactive learning. Furthermore, AI-supported assessment and personalized learning systems enable students to learn at their own pace while receiving tailored guidance and feedback. These capabilities not only enhance learning outcomes but also promote inclusive, equitable, and learner-centered education.

More specifically, this study focused on AI tools developed for mathematics education. A wide range of AI-based tools are currently available for students up to the secondary education level (up to Grade 12); however, a significant gap was identified in the availability of AI tools tailored for engineering mathematics at the college level. Such tools could play a crucial role in supporting undergraduate students in understanding complex mathematical concepts.The other limitations include restricted access to the tools due to cost, and reduced student–teacher interaction due to use of AI tools. Therefore, AI should be adopted in a responsible and balanced manner, primarily as a supportive tool for time-intensive tasks and personalized assistance, while preserving the essential role of human interaction in education. The inclusion of examples from sustainable real work implementation is mathematical education for technical courses will not only enhance the awareness about SDG4 but it will also contribute in a strong youth force building for a brighter future.

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