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ANCIENT INDIAN MATHEMATICAL WISDOM AND MODERN INNOVATION: A REVIEW OF MATHEMATICAL DEVELOPMENT, RESEARCH, SKILL FORMATION, AND VIKSIT BHARAT 2047

Harinder Kaur

Department of Mathematics,, Mata Ganga Khalsa College, Manji Sahib, Kottan, District Ludhiana, Punjab, India

ABSTRACT

Mathematics is a fundamental driver of scientific discovery, technological progress, economic analysis, and national development. Ancient Indian mathematical traditions made significant contributions to numerical representation, arithmetic, algebra, geometry, and mathematical astronomy. The work of Aryabhata, Brahmagupta, Mahavira, and Bhaskara II illustrates the development of systematic mathematical reasoning in response to scientific and practical problems. In the contemporary period, mathematics is undergoing further transformation through artificial intelligence (AI), automated theorem proving, formal verification, computational modelling, optimization, and data science.

This review connects historically documented Indian mathematical achievements with recent developments in mathematical research and India's innovation ecosystem. Quantitative evidence reported in 2026 includes AI-assisted formal proof research that reported solutions to nine of 353 open Erdős problems and proofs of 44 of 492 conjectures from the On-Line Encyclopedia of Integer Sequences. A separate project reported a formal mathematics library containing more than 45,000 declarations and approximately 500,000 lines of code. Indian research indicators are also examined, including gross expenditure on research and development (GERD) of ₹2, 44,767.81 crore, equivalent to 0.84% of GDP in 2023–24, according to a government statement published in 2026.

The paper adopts a narrative review methodology and interprets these developments through mathematical concepts, quantitative indicators, research infrastructure, and innovation policy. It argues that a development strategy combining mathematical foundations, computational methods, historical awareness, and rigorous verification can contribute to India's aspiration of Viksit Bharat 2047.

Keywords: Ancient Indian mathematics, mathematical innovation, algebra, geometry, artificial intelligence, formal verification, computational mathematics, mathematical modelling, research and development, Viksit Bharat 2047.

1. INTRODUCTION:

Mathematics provides the conceptual and quantitative foundations for scientific research, engineering, computing, economics, environmental analysis, and technological innovation. It enables complex phenomena to be represented through equations, statistical models, algorithms, and logical structures. Its contribution extends beyond calculation: mathematics helps establish relationships, test hypotheses, quantify uncertainty, and determine whether conclusions follow logically from stated assumptions.

Ancient India occupies an important place in the history of mathematical thought. Developments in numerical notation, arithmetic, algebra, geometry, trigonometry, and mathematical astronomy emerged through sustained intellectual work and practical applications. These achievements should be interpreted within their historical contexts and supported by reliable scholarly evidence (Plofker, 2009).

Contemporary mathematical research is also changing rapidly. Artificial intelligence systems can assist in exploring conjectures and generating candidate proofs, while proof assistants can check formal arguments. Computational mathematics makes it possible to investigate complicated systems through numerical approximation and simulation. Optimization and statistical modelling are increasingly important in engineering, scientific computing, finance, and AI.

India's development ambitions make these advances particularly relevant. The capacity to undertake mathematical research, develop computational tools, and apply quantitative reasoning is linked to research infrastructure, technical expertise, institutional collaboration, and investment in science and technology. A government statement published in 2026 reported that India's GERD had reached ₹2, 44,767.81 crore in 2023–

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24, or 0.84% of GDP, highlighting both the scale of research activity and the importance of strengthening the research ecosystem (Press Information Bureau [PIB], 2026).

This paper reviews selected contributions of ancient Indian mathematics, examines recent mathematical innovations using quantitative evidence, and analyses their implications for research, skill formation, and Viksit Bharat 2047.

2. OBJECTIVES OF THE REVIEW

- To review significant, historically documented contributions of ancient Indian mathematics.
- To explain selected mathematical concepts through equations and numerical examples.
- To examine recent innovations in AI-assisted mathematical discovery and formal verification.
- To analyse current quantitative indicators of mathematical research and India's wider research ecosystem.
- To discuss the role of mathematical modelling, optimization, and data analysis in technological development.
- To identify challenges related to reliability, research infrastructure, funding, and responsible innovation.
- To recommend measures for strengthening mathematics-led innovation in the context of Viksit Bharat 2047.

3. REVIEW METHODOLOGY

This paper uses a narrative review approach based on scholarly histories of mathematics, historical mathematical editions, official government publications, research announcements, and recent scientific reports. Historical material is drawn primarily from Plofker (2009) and the scholarly edition of the Āryabhaṭīya edited by Shukla and Sarma (1976).

For contemporary developments, the review examines reports published in 2026 by the scientific journal Science, Meta's AI research group, ETH Zurich, India's Department of Science and Technology, and the Government of India's Press Information Bureau. Quantitative values are reported with their stated denominators, units, and reference periods wherever available.

4. HISTORICAL FOUNDATIONS OF ANCIENT INDIAN MATHEMATICS

Decimal place-value notation

The decimal place-value system is one of the most influential developments associated with Indian mathematical traditions. Its central principle is that the value of a digit depends on its position within a number.

The place-value system enables systematic arithmetic and the efficient representation of large numbers. Its historical development occurred over time and should be understood through the evolution of Indian numerals and their transmission across mathematical cultures (Plofker, 2009).

Positional notation provides a foundation for algorithms, numerical computation, scientific notation, and digital representation. The efficiency of modern numerical systems depends substantially on the ability to represent quantities consistently and perform operations according to established rules.

Aryabhata and mathematical astronomy

Aryabhata composed the Āryabhaṭīya in the fifth century CE. His work included arithmetic, algebraic procedures, trigonometric values, and mathematical astronomy (Shukla & Sarma, 1976).

Mathematical astronomy required numerical methods to represent periodic motion, estimate positions, and calculate quantities associated with celestial phenomena. Such applications illustrate the importance of connecting mathematical abstraction with observations and scientific questions.

Aryabhata's work demonstrates how mathematical tables, numerical procedures, and geometrical relationships can support scientific calculations. It also provides a historical example of mathematics functioning as a quantitative language for describing the natural world.

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Brahmagupta and algebraic operations

Brahmagupta, a seventh-century mathematician, made influential contributions to arithmetic and algebra. His Brahmasphutasiddhanta addressed operations involving positive and negative quantities, zero, and equations (Plofker, 2009).

The development of rules for signed numbers and zero is fundamental to algebra, numerical analysis, financial modelling, and the representation of quantities that can vary above or below a reference value.

Mahavira and Bhaskara II

Mahavira, a ninth-century mathematician, wrote the Ganitasarasangraha, which treated arithmetic and mathematical problems. Bhaskara II, a twelfth-century scholar, made substantial contributions to arithmetic, algebra, and astronomy through works including the Lilavati and Bijaganita (Plofker, 2009).

Algebra provides a general framework for representing unknown quantities and deriving relationships between them.

The significance of algebra lies not only in finding a particular answer but also in developing general methods that can be applied to many problems. Equations can represent financial relationships, mechanical systems, production costs, and scientific laws. The historical development of arithmetic and algebra illustrates the importance of symbolic representation, systematic operations, and general solution procedures in quantitative reasoning.

Geometry and the Śulbasūtras

The Śulbasūtras are early Sanskrit texts containing geometric procedures associated with the construction of ritual spaces. They include instructions involving measurement, shapes, and relationships between lengths (Plofker, 2009).

Geometry supports measurement, architecture, surveying, structural analysis, computer graphics, and spatial modelling. Its combination of visual representation and logical deduction remains central to many technical fields.

5. RECENT INNOVATIONS IN MATHEMATICS:

Recent mathematical innovation increasingly combines human mathematical expertise with computation, AI, formal logic, and large-scale research collaboration. The following examples illustrate the scale and nature of selected developments reported in 2026.

- **AI-assisted formal proof search**

  A research paper published in Science on 8 October 2026 described an AI agent designed to search for formal mathematical proofs .The results suggest that AI can help search large spaces of possible arguments, particularly where candidate proofs can be formalized and checked.

- **Formalizing mathematical knowledge at scale**

  In May 2026, Meta's AI research group reported AutoformBot, a multi-agent system for translating mathematical textbook content into machine-checkable Lean 4 definitions and proofs. The associated project reported a library containing more than 45,000 Lean declarations and approximately 500,000 lines of code, derived from 26 open-access textbooks covering analysis, algebra, topology, combinatorics, and probability (Meta AI, 2026).

- **AI performance on research-level mathematics**

  ETH Zurich reported in July 2026 that its team achieved the best result in the First Proof Challenge, solving 6 of 10 research-level mathematical problems using an agent-based AI system (ETH Zurich, 2026).

6. MATHEMATICAL FOUNDATIONS OF AI: INDIA–FRANCE RESEARCH COOPERATION

On 19 February 2026, India's Department of Science and Technology and France's National Research Agency announced a joint call for proposals in applied mathematics and artificial intelligence. The call identified four broad research areas:

- Mathematical foundations of AI.
- Theoretical foundations of optimization and AI.

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- Mathematics for safe, trustworthy, and reliable AI.
- AI modelling for partial differential equations (PDEs), and PDE modelling for AI (DST, 2026).

The fourth area is particularly significant from a mathematical perspective. Partial differential equations describe quantities that vary across space and time, including temperature, fluid flow, waves, and many physical processes.

AI-based methods may assist with approximating solutions, estimating unknown parameters, or learning patterns from simulated and observed data. However, any such method must be assessed for stability, accuracy, computational cost, and consistency with the governing physical laws.

The research agenda highlights a two-way relationship. Mathematics supports the development and analysis of AI, while AI may provide new computational methods for solving mathematical and scientific problems.

6.1India's Research and Innovation Ecosystem

India has demonstrated a substantial increase in gross expenditure on research and development, accompanied by growing private-sector participation. However, sustaining research-led development will require continued investment, effective allocation of funds, stronger collaboration between research institutions and industry, and measurable outcomes in scientific discovery and technological innovation.

A statement published by the Press Information Bureau on 12 August 2026, drawing on the Department of Science and Technology's Research and Development Statistics 2025–26, reported the following indicators for India (PIB, 2026).

Table: Gross Expenditure on R&D as a Share of GDP in India (2019–20 to 2023–24)

Financial year	GERD(Rs Crores)	GERD as % of GDP	Government Share (%)
2019-20	1,32,546.01	0.66	66.2
2020-21	1,27,380.96	0.64	63.6
2021-22	1,94,810.83	0.83	54.5
2022-23	2,13,378.12	0.82	52.0
2023-24	2,44,767.81	0.84	48.2

(Source: Department of Science and Technology (DST), Research & Development Statistics 2025–26, as reported by the Government of India.)

6.2 **Major national programmes relevant to mathematical innovation**

The August 2026 government statement also reported 25 Technology Innovation Hubs under the National Mission on Interdisciplinary Cyber-Physical Systems and four Technology Hubs under the National Quantum Mission (PIB, 2026).

Programme	Reported outlay	Mathematical and technological relevance
Research, Development and Innovation Fund	₹1,00,000 crore	Deep technology, including AI, quantum computing, robotics, and the digital economy
India AI Mission	₹10,371.92 crore	AI infrastructure and ecosystem development, including computational methods
National Quantum Mission	₹6,003.65 crore	AI, robotics, cybersecurity, and interconnected physical-digital systems
National Mission on Interdisciplinary Cyber-Physical Systems	₹3,660 crore	AI, robotics, cybersecurity, and interconnected physical-digital systems
India Semiconductor Mission	₹76,000 crore	Semiconductor fabrication, packaging, design, and the wider semiconductor ecosystem

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These figures indicate a distributed infrastructure for research and technology development. The effectiveness of such infrastructure depends on the quality of research, availability of specialist personnel, access to computational resources, collaboration among institutions, and the ability to translate research into verified applications. Mathematics contributes to these areas in different ways:

- AI: linear algebra, probability, statistics, optimization, and numerical analysis.
- Quantum computing: linear algebra over complex vector spaces, operator theory, probability, and computational complexity.
- Cyber-physical systems: differential equations, control theory, optimization, graph theory, and numerical simulation.
- Semiconductors: partial differential equations, computational electromagnetics, numerical methods, and optimization.
- Deep technology: mathematical modelling, algorithm design, uncertainty quantification, and formal verification.

7. MATHEMATICS, RESEARCH SKILLS, AND NATIONAL DEVELOPMENT

Mathematical innovation requires more than the availability of AI tools or computing infrastructure. It also depends on the ability to formulate precise questions, choose appropriate methods, interpret evidence, and distinguish valid conclusions from unsupported claims. Research and technical capability can be strengthened through the following priorities:

- Foundational mathematical competence: algebra, geometry, calculus, probability, statistics, discrete mathematics, and numerical methods.
- Computational capability: scientific programming, algorithm design, data handling, and reproducible numerical analysis.
- Formal reasoning: proof construction, logic, verification, and the careful specification of assumptions.
- Interdisciplinary collaboration: cooperation among mathematics, computer science, physics, engineering, economics, and other research areas.
- Research integrity: transparent methods, appropriate attribution, independent validation, and clear reporting of limitations.
- Innovation evaluation: assessment of accuracy, reproducibility, practical value, resource requirements, and long-term sustainability.

In the context of Viksit Bharat 2047, these priorities can help connect mathematical research with industrial innovation, scientific development, and evidence-based decision-making. Historical mathematical achievements provide important intellectual context, while contemporary mathematical methods offer tools for addressing present and future challenges.

8. LIMITATIONS AND CHALLENGES

- Historical texts often use terminology and methods that differ from modern mathematical conventions. Historical claims should be based on reputable editions and scholarly interpretations, and modern notation should not be attributed to earlier texts without evidence.
- AI systems may generate invalid arguments, overlook assumptions, or produce proofs that are difficult to interpret. Formal verification can check a proof within a specified logical framework, but the formulation of the theorem and the correctness of its formalization still matters
- Advanced mathematical research may require high-performance computing, specialized software, reliable data, and expert personnel. Unequal access to these resources can constrain research capacity. Institutional investment must therefore be accompanied by sustained technical support and effective collaboration.
- Mathematical and AI-based systems can influence important decisions. Their use requires attention to reliability, uncertainty, reproducibility, data quality, privacy where relevant, and accountability for results.

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9. **RECOMMENDATIONS**

- Strengthen mathematical foundations:

  Support advanced work in algebra, analysis, geometry, probability, statistics, optimization, and discrete mathematics.

- Expand formal verification:

  Encourage research using proof assistants and machine-checkable mathematical libraries, while maintaining independent mathematical review.

- Adopt transparent benchmarks:

  Require AI-assisted mathematics research to report problem selection, denominators, verification procedures, failed attempts where relevant, and limitations.

- Improve research metrics:

  Supplement expenditure data with inflation-adjusted investment, research capacity, verified outputs, reproducibility, and long-term outcomes.

- Develop interdisciplinary programmes:

  Link pure mathematics with AI, quantum technologies, scientific computing, engineering, and data science.

- Support open research infrastructure:

  Promote reusable mathematical software, open data where appropriate, and carefully documented computational workflows.

- Strengthen research collaboration:

  Build sustained links among universities, research institutes, government programmes, and industry.

- Maintain historical accuracy:

  Use reliable sources to interpret ancient Indian mathematics and avoid unsupported claims about priority or direct influence.

- Promote responsible AI use:

  Require mathematical verification, appropriate attribution, and explicit disclosure of the role of automated systems in research.

- Evaluate long-term impact:

  Assess whether funded initiatives produce reliable research, useful technology, stronger research capability, and demonstrable public value.

10. **CONCLUSION**

Ancient Indian mathematics made important contributions to numerical representation, arithmetic, algebra, geometry, and mathematical astronomy. The work of Aryabhata, Brahmagupta, Mahavira, Bhaskara II, and the traditions represented by the Śulbasūtras demonstrates the historical development of systematic mathematical reasoning.

Contemporary mathematics is undergoing further change through AI-assisted proof search, formal verification, computational modelling, optimization, and data science. Reported results from 2026, including AI-assisted solutions to selected open mathematical problems, the development of large formal proof libraries, and research-level proof challenges, provide measurable examples of this transition. Their significance must be assessed through rigorous verification, transparent benchmarks, and independent scholarly scrutiny.

India's reported GERD of ₹2,44,767.81 crore, or 0.84% of GDP, in 2023–24, together with major programmes supporting AI, quantum technologies, and research infrastructure, illustrates the scale of the national research ecosystem. These indicators provide useful context but cannot, by themselves, establish research productivity or technological impact. Evaluation must connect financial inputs with verified outputs, research quality, and practical outcomes.

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For Viksit Bharat 2047, mathematics should be regarded as a foundational capability rather than a supporting subject confined to calculation. Its contributions to scientific modelling, reliable AI, optimization, quantitative policy analysis, and technological development make it central to a knowledge-based economy. Combining historical awareness with rigorous contemporary mathematics, computational capability, and responsible innovation can strengthen India's long-term research and development capacity.

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