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The impact of AI on mathematical research

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Abstract
Artificial intelligence (AI) has emerged as a transformative force in mathematical research, reshaping the methods by which mathematicians discover, formulate, and verify results. This paper examines the multifaceted impact of AI on contemporary mathematics, covering landmark achievements in automated theorem proving and problem solving, the evolving paradigm of human-AI collaboration in both pure and applied mathematics, the epistemological question of novel concept creation, and the ethical dimensions of AI-assisted research. We argue that while AI currently excels as a powerful computational collaborator identifying patterns, generating conjectures, and rigorously verifying proofs, the creation of genuinely new mathematical concepts remains a distinctly human endeavour requiring intuition, abstraction, and intellectual struggle. Properly cited human-AI collaboration represents not a threat but an enrichment of the mathematical enterprise, provided that human scrutiny, rigorous verification, and transparent attribution are maintained. We conclude with reflections on the implications for skill development and the enduring value of the mathematical struggle that produces genuine understanding.

Keywords: Artificial intelligence, mathematical research, human-AI collaboration, theorem proving, concept creation, applied mathematics, research ethics

Introduction

Mathematics has long been regarded as the domain of pure human intellect-a discipline in which intuition, creativity, and rigorous logical reasoning converge to produce lasting truth. Yet, since the latter decades of the twentieth century, computational tools have steadily entered the mathematician's toolkit: from symbolic algebra systems such as Mathematica and Maple, to SAT solvers that assisted in the proof of the Four Color Theorem [1], to automated theorem provers that can verify thousands of lemmas in seconds. The twenty-first century, however, has witnessed acceleration qualitatively different from any prior development. The rise of large language models (LLMs) and reinforcement learning-based systems have produced AI that can engage with mathematics not merely as a calculator but as something approaching a reasoning partner [2].

The evidence is striking. As recently as 2021, the state-of-the-art GPT-3 could not solve more than 35% of grade-school mathematics problems. By early 2024, leading models were solving more than 50% of high-school competition problems, and by 2025 OpenAI's o3 and o4-mini achieved near-perfect accuracy on the American Invitational Mathematics Examination (AIME 2024 and 2025), surpassing virtually all human competitors [3]. In July 2024, Google DeepMind's AlphaGeometry and AlphaProof earned a silver medal at the International Mathematical Olympiad (IMO); one year later, Gemini Deep Think secured a gold medal by solving problems entirely autonomously in natural language within the 4.5-hour competition limit [4]. These are not incremental improvements; they represent a step change in the relationship between artificial intelligence and mathematics.

This paper examines that relationship systematically. Section 2 surveys landmark AI achievements in mathematical problem-solving and proof verification. Section 3 analyses the paradigm of human-AI collaboration, distinguishing its role in pure mathematics (novel structure creation and conjecture generation) from its role in applied mathematics (modelling and boundary-value problems). Section 4 addresses the crucial question of whether AI can independently create new mathematical concepts. Section 5 treats the ethical dimensions of AI-assisted research, including citation norms and academic integrity. Section 6 discusses implications for skill development and the pedagogical value of mathematical struggle. Section 7 offers conclusions and a prospective assessment of the field.

Landmark Ai Achievements in Mathematics

The most dramatic demonstrations of AI capability in mathematics have occurred in the realm of competition mathematics and formal proof verification. AlphaGeometry, a neuro-symbolic system combining a neural language model with a symbolic deduction engine, solved 25 of 30 IMO geometry problems at a level comparable to an average gold medallist [5]. Its successor AlphaProof extended this capability to algebraic and number-theoretic reasoning using the Lean 4 proof assistant. These systems required expert mathematicians to translate problems into machine-readable form and ran computations over several days-a reminder of the continued indispensability of human expertise in the loop [4].

In the domain of discovery rather than competition, AlphaEvolve-an evolutionary coding agent developed at Google DeepMind was applied to 67 open mathematical problems across several areas. On 23 of these it improved upon the best known solutions; on 36 it matched them. Mathematician Javier Gómez-Serrano, who collaborated with the system alongside Terence Tao and Adam Zsolt Wagner, observed that results comparable to those an expert might achieve in several months were obtained in one to two days [6]. Tao himself described current AI models as "very good at scouring big lists of problems for low-hanging fruit"-a candid and precise characterisation of their current comparative advantage.

In formal proof verification, the Gauss agent demonstrated the power of human-AI collaboration by formalising the strong Prime Number Theorem in Lean 4 within three weeks, leveraging expert scaffolding [7]. Separately, the Numina-Lean-Agent formalised a research paper on Brascamp–Lieb inequalities through iterative refinement of a natural language blueprint [7]. These achievements have catalysed a significant institutional response: in December 2024, Renaissance Philanthropy and XTX Markets announced $18 million in grants through the AI for Math Fund, supporting 29 projects at leading universities, with individual awards up to $1 million, to advance AI-assisted mathematical discovery [8]. The trajectory is unmistakable: AI is no longer a peripheral computational aid but a central participant in the research enterprise.

Human–Ai Collaboration in Pure and Applied Mathematics

1. Pure Mathematics: Conjecture, Pattern Recognition, and Novel Structures

The complementarity between machine and human strengths provides a natural framework for collaboration. AI systems, leveraging vast computational power and pattern-recognition capabilities, serve as exploratory tools across high-dimensional mathematical datasets. Humans, in turn, analyse, interpret, and filter machine-generated patterns to extract meaningful insights, propose conjectures, and develop theories [2]. This division of cognitive labour has produced tangible results in several branches of pure mathematics.

A paradigmatic example is the 2021 collaboration between DeepMind and mathematicians at Oxford and Sydney, which used supervised machine learning to discover a new connection between the algebraic and geometric structure of knots, and to identify a candidate algorithm for the combinatorial invariance conjecture for symmetric groups [9]. More recently, a human-AI collaboration in combinatorial design theory-combining an LLM-powered AI agent with symbolic computation tools and human strategic direction-produced a tight lower bound on the imbalance of Latin squares for the case $n \equiv 1 \pmod 3$, formally verified in Lean 4 [10]. The authors observed that the AI agent proved effective at uncovering hidden structure and generating hypotheses, while human steering supplied the critical research pivot that transformed a dead end into a productive inquiry.

A human mind possessing even a rough intuition about a mathematical structure can provide conceptual inputs to AI systems, which are then able to construct the structure with full mathematical rigor: axioms, definitions, lemmas, and proofs. The further development of theory can then proceed collaboratively, with the human providing the guiding mathematical vision and the AI providing the combinatorial and logical machinery to realize it. This pipeline is especially promising for the construction of novel algebraic, topological, and metric structures in pure mathematics-areas where the key conceptual leaps remain human achievements but their rigorous elaboration can be substantially accelerated.

2. Applied Mathematics: Modelling and Boundary-Value Problems

In applied mathematics, the case for AI assistance is perhaps even more immediate. When presented with physical or engineering situation-including boundary conditions, initial data, domain geometry, and governing physical laws AI systems can assist substantially in model formulation, in selecting appropriate analytical or numerical methods, and in deriving or approximating solutions. Multi-agent architectures such as the AIM (AI Mathematician) framework implement distinct Explorer, Verifier, and Optimizer agents that cooperate on complex partial differential equation (PDE) and homogenization theory problems [11].

Reinforcement learning and neural network-based PDE solvers (such as Physics-Informed Neural Networks) have demonstrated the ability to approximate solutions to high-dimensional equations that lie beyond the reach of classical numerical methods. Large language models assist applied mathematicians in literature synthesis, in identifying analogous models from adjacent fields, and in the rapid prototyping of computational experiments. The 2024 Nobel Prize in Chemistry, awarded to Demis Hassabis and John Jumper for AlphaFold2's prediction of the structures of approximately 200 million known proteins, demonstrates the extent to which AI can constitute a genuine scientific breakthrough in an applied domain rooted in mathematical optimization [12].

The Question of Novel Concept Creation

The most philosophically significant question raised by AI's incursion into mathematics is whether machines can create genuinely new mathematical concepts not merely derive consequences of existing ones, but introduce the abstract structures, definitions, and organizing ideas that give mathematics its forward momentum. The current consensus among leading researchers is that this capacity remains distinctly human.

Erika Abraham of RWTH Aachen University has observed that while AI may manage to prove certain theorems, it struggles to generate the abstract concepts that give rise to those theorems-an integral component of mathematical innovation [13]. Melanie Mitchell of the Santa Fe Institute similarly notes that although AI can confirm the truth of established results, it falters at deriving high-level abstractions [13]. The analysis of mechanical concept creation by Sawin (2025) argues that humans invest in explicit concepts precisely because human computation is weak: human mathematics is concept-heavy because human working memory is severely limited, and new concepts are the cognitive tools that make the remaining search tractable [14]. Machines, with their vastly superior raw computational power, may approach problems through very different trade-offs-and may lack the evolutionary and cultural pressures that make human-style conceptual economy necessary.

This does not diminish the value of AI as a conceptual assistant. There is a meaningful intermediate category between fully autonomous concept creation and rote computation: AI systems that, guided by a human mathematician's rough intuition, can propose refined definitions suggest axiom systems, generate counterexamples that refute premature generalizations, and identify structural analogies across disparate areas of mathematics. In this assistive mode, the human provides the conceptual seed and the motivating mathematical vision; the AI provides the rigorous elaboration and the combinatorial exploration. The result is a genuinely collaborative intellectual product that neither party could have produced alone.

Ethical Dimensions: Citation, Attribution, and Integrity

The use of AI in mathematical research raises ethical questions that the mathematical community is only beginning to address. The central issue is attribution: when an AI system contributes substantially to a proof, a conjecture, or a model, who is the intellectual author of the result? A 2025 analysis published in AI and Ethics argues that current theorem-proving tools occupy an ethical grey zone-they may autonomously generate new proofs, yet their contributions are rarely acknowledged in ways commensurate with their role [15].

We argue that properly cited human-AI collaboration raises no fundamental ethical objection, provided that the following conditions are met. First, the human researcher must maintain genuine intellectual engagement with the research problem-providing the mathematical vision, interpreting the AI's outputs critically, and taking intellectual responsibility for the results. Second, the use of AI tools must be transparently disclosed in submitted manuscripts, with sufficient methodological detail that readers can assess the nature and extent of AI involvement. Third, human scrutiny of all AI-generated results is essential: AI systems hallucinate, produce plausible-sounding but incorrect arguments, and cannot reliably self-verify-a point underscored by Tao's observation that models achieve "scattered successes among a big sea of unreported failures" [6].

The Bulletin of the American Mathematical Society devoted two special issues in 2024 to the intersection of AI and mathematics [16], and leading journals are now developing explicit policies on AI disclosure. The $18 million AI for Math Fund explicitly funds the development of verifiable training corpora and "adversarial collaboration" methodologies to identify logical gaps in AI-generated mathematics [8]. The emerging norm appears to be that AI should be treated as a sophisticated tool-analogous to, but more powerful than, a computer algebra system-with its use disclosed and its outputs verified by human experts before publication.

Implications for Skill Development and Mathematical Education

Perhaps the most humanly resonant concern raised by AI in mathematics is its potential impact on the development of mathematical skill, particularly in the next generation of researchers. The worry is not unfounded: if AI can solve competition problems, verify lemmas, and suggest proof strategies on demand, the cognitive struggle that has historically been the source of mathematical mastery may be short-circuited.

Researchers in mathematics education have observed a growing tension between AI as an efficiency tool and AI as a potential inhibitor of deep learning. When used by students or non-experts, AI tools often provide incomplete, superficial, or outright incorrect solutions to mathematical problems; unlike experienced researchers who can validate AI outputs through numerical checks, literature reviews, or alternative derivations, students may accept AI answers uncritically. This mismatch in expertise creates a risk that AI could reinforce misconceptions and weaken the development of rigorous problem-solving skills. Many mathematicians argue, consequently, that AI should be reserved for expert use, where it serves as a catalyst rather than a crutch.

Yet there is a deeper point about the nature of mathematical understanding that transcends pedagogical strategy. The joy of mathematics lies substantially in the struggle-in the sustained encounter with difficulty, the moment of insight that resolves a long-standing confusion, the eureka instant when a pattern suddenly becomes clear. This phenomenology of mathematical discovery is not merely an epiphenomenon of the process; it is constitutive of the mathematician's understanding. A proof that one has verified but not genuinely followed is not fully understood; a theorem that one has been told but not worked towards is not fully possessed. AI can accelerate the formal production of results, but it cannot substitute for the intellectual formation that the struggle produces.

The appropriate response is not to resist AI but to integrate it thoughtfully. A 2025 systematic review of AI in mathematics education recommends that curricula be revised to emphasize high-level reasoning, problem formulation, and critical evaluation of AI outputs as core competencies. The mathematician of the future will need to be not only a solver of problems but a discerning collaborator with AI systems-capable of providing mathematical vision, verifying machine outputs, and maintaining the standards of rigor that have always distinguished genuine mathematical knowledge from mere computation.

Conclusion

Artificial intelligence has entered mathematical research as a genuinely transformative force, not as a distant prospect but as a present reality. Systems such as AlphaProof, AlphaEvolve, and Gemini Deep Think have achieved results in competition mathematics and formal proof verification that were unimaginable a decade ago. Human-AI collaboration has produced new results in pure mathematics from knot theory to combinatorial design theory and has accelerated applied mathematical modelling in ways that are beginning to reshape entire scientific fields.

The creation of genuinely new mathematical concepts, however, remains a distinctly human achievement. The conceptual leaps that give mathematics its direction-the introduction of new structures, the identification of deep analogies, the formulation of problems worth solving require the kind of motivated, embodied, culturally situated intelligence that current AI systems do not possess. The productive future of mathematical research lies not in the replacement of human mathematicians but in a principled collaboration in which human conceptual creativity and AI computational power each contribute what the other cannot.

For this collaboration to serve mathematics well, it must be ethically grounded: transparently disclosed, rigorously verified, and properly attributed. It must also be pedagogically conscious: the struggle of mathematical formation must not be surrendered to the convenience of AI assistance, for it is in that struggle that genuine mathematical understanding and the next generation of human mathematical insight is forged.

References

1. Appel K, Haken W. Every planar map is four colorable. Illinois Journal of Mathematics,1977:21(3):429–490.
2. Chen X, et al. Mathematics and machine creativity: A survey on bridging mathematics with AI. arXiv:2412.16543, 2024.

3. Liu Y, et al. AI Mathematician: Towards fully automated frontier mathematical research. arXiv:2505.22451, 2025.
4. Hartmann M, et al. The mathematician's assistant: Integrating AI into research practice. arXiv:2508.20236, 2025.
5. Trinh T, et al. Solving olympiad geometry without human demonstrations. Nature, 2024, 625, 476–482.
6. Georgiev B, Gómez-Serrano J, Tao T, Wagner AZ. Mathematical exploration and discovery at scale. arXiv:2511.02864, 2025.
7. Hayat A, et al. AI for mathematics: Progress, challenges, and prospects. arXiv:2601.13209, 2026.
8. Renaissance Philanthropy and XTX Markets. AI for Math Fund announces $18 million in grants. December 2024. [Online]. Available: https://www.renaissancephilanthropy.org.
9. Davies A, et al. Advancing mathematics by guiding human intuition with AI. Nature, 2021, 600, 70–74.
10. Xia H, Gomes CP, Selman B, Szeider S. Agentic neurosymbolic collaboration for mathematical discovery: A case study in combinatorial design. arXiv:2603.08322, 2026.
11. Liu Y, et al. AI Mathematician (AIM): Multi-agent architectures for frontier mathematical research. arXiv:2505.22451, 2025.
12. Jumper J, et al. Highly accurate protein structure prediction with AlphaFold. Nature, 2021, 596, 583–589.
13. Castelvecchi D. Is AI ready to do mathematical research? Nature News, 2023.
14. Sawin S. On the mechanical creation of mathematical concepts. arXiv:2507.10179, 2025.
15. Somló G. The need for ethical guidelines in mathematical research in the time of generative AI. AI and Ethics, Springer, 2025. doi:10.1007/s43681-025-00660-5.
16. Special issues on AI and mathematics. Bulletin of the American Mathematical Society, 2024, 61.