Is mathematics obsolete?

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Mathematics vs. science

Philosophers have long recognized a distinction between mathematical and scientific reasoning.

Mathematics	**Science**
about abstract objects	about the world
neither temporal nor spatial	objects in time and space
rational	empirical
deductive	inductive
from axioms to conclusions	from data to laws
certain	fallible
exact, precise	approximate

Mathematics vs. science

This has played out in philosophy in various ways:

- rationalists vs. empiricists in early modern philosophy
- a priori vs. a posteriori in Kant
- analytic / synthetic distinction in twentieth century philosophy

What is at stake:

- ontology: the nature of the objects involved
- epistemology: the proper means of justification
- personal preference

Certainly mathematics and science need each other: "Thoughts without content are empty, and intuitions without concepts are blind."

Two paradigms for AI

"There are two quite different paradigms for AI. Put simply, the logic-inspired paradigm views sequential reasoning as the essence of intelligence and aims to implement reasoning in computers using hand-designed rules of inference that operate on hand-designed symbolic expressions that formalize knowledge. The brain-inspired paradigm views learning representations from data as the essence of intelligence and aims to implement learning by hand-designing or evolving rules for modifying the connection strengths in simulated networks of artificial neurons."

(Yoshua Bengio, Yann Lecun, and Geoffrey Hinton, 2018 Turing Award winners)

A brief history of symbolic AI

Timeline:

- Early twentieth century: axiomatic foundations and decision procedures
- 1940s: first digital computers
- 1956: Dartmouth Summer Research Project on Artificial Intelligence
- 1960s: optimism
- 1970s: disappointment
- 1980s: expert systems, Japan's Fifth Generation Computer Systems project
- 1990s: AI winter (despite Deep Blue)

The symbolic paradigm

Influences:

- cognitive science (symbolic representations, rules of reasoning)
- linguistics and natural language processing (formal grammars, formal semantics)
- automated reasoning (logical rule-based search)
- computer vision (extracting symbolic representations)

The rise of machine learning

Turning points:

- 1990s: big data, statistical methods
- 2011: IBM's Watson wins Jeopardy
- 2012: AlexNet wins ImageNet
- 2016: AlphaGo beats Lee Sedol
- 2022: ChatGPT released

The rise of machine learning

Shifts at Carnegie Mellon:

- Influence of Herbert Simon and Allen Newell in the 1950s and 1960s.
- Logic played a prominent role in Computer Science, Mathematics, Philosophy, Psychology, Linguistics.
- First academic department of Machine Learning in 2006.
- First undergraduate AI major in 2018.

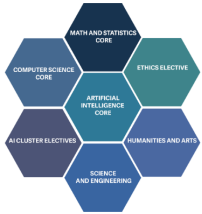
Neural vs. symbolic AI

The web pages for the major include an overview, degree requirements, and a sample curriculum.

Degree Requirements

BSAI majors will take courses in math and statistics, computer science, AI, science and engineering, and humanities and arts. There's also room built into the curriculum for academic exploration via electives. We've included information about how the curriculum breaks down below.

You can learn more about how a typical student may complete this degree on our BSAI Roadmap.



Neural vs. symbolic AI

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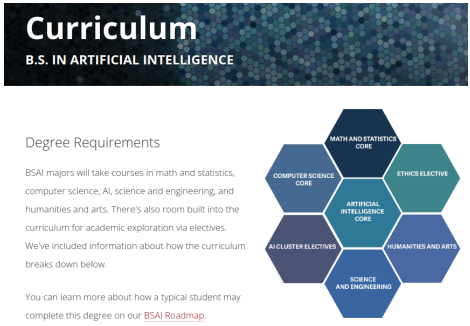


The word “logic” does not appear anywhere.

Neural vs. symbolic AI

From the *New York Times*
April 4, 2023

What is artificial intelligence?

Let's start at the beginning.

The term "artificial intelligence" gets tossed around a lot to describe robots, self-driving cars, facial recognition technology and almost anything else that seems vaguely futuristic.

A group of academics coined the term in the late 1950s as they set out to build a machine that could do anything the human brain could do — skills like reasoning, problem-solving, learning new tasks and communicating using natural language.

Progress was relatively slow until around 2012, when a single idea shifted the entire field.

It was called a **neural network**. That may sound like a computerized brain, but, really, it's a mathematical system that learns skills by finding statistical patterns in enormous amounts of data. By analyzing thousands of cat photos, for instance, it can learn to recognize a cat. Neural networks enable Siri and Alexa to understand what you're saying, identify people and objects in Google Photos and instantly translate dozens of languages.

Is mathematics obsolete?

To some extent, I am conflating

- mathematical reasoning vs. scientific reasoning with
- symbolic methods vs. machine learning.

To be sure, mathematics requires creativity, intuition, experience, big ideas, and deep insights.

But one of the hallmarks of mathematical reasoning is that it employs symbolic reasoning with precise rules and concepts.

Modern AI threatens to replace that.

For those of us who use symbolic methods, the feeling of anxiety is visceral.

Is mathematics obsolete?

Mathematical ideas have supported scientific exploration and practical reasoning for centuries.

Given our limited cognitive abilities, mathematical abstraction has been a valuable tool.

But now that we have neural networks to process the data and tell us what to make of it, maybe the idealized mathematical representations we have been using are less helpful.

Perhaps symbolic methods are no longer important because mathematical reasoning is no longer important: technology has given us something better.

Is mathematics obsolete?

There is a strong aesthetic component to mathematics.

- We do mathematics because it is useful.
- We do mathematics because it is beautiful, and because we enjoy it.

But part of the aesthetic is that mathematics, and precise, rigorous thought, is broadly useful.

And maybe modern technology will change that.

I, personally, think that, in the age of AI, mathematics and symbolic methods are more important than ever.

But that's not something we can take for granted.

The value of mathematics

Generally, when we ask ChatGPT a question, we want the answer to be

- reliable,
- aligned with our interests,
- likely to help us achieve our goals.

We worry about:

- safety and security
- values and morals.

The value of mathematics

We want transparency:

- reasons
- explanations
- justification.

This provides one role for mathematics.

But it does go far enough: it presupposes that AI has all the answers, and only needs to explain them to us.

It puts AI, rather than us, at the center of our deliberative processes.

The value of mathematics

Imagine you are the mayor of a small town, and the town council wants to new bridge.

You say to ChatGPT, “design us a bridge!”

The value of mathematics

Maybe we want:

- blueprints, with precise lengths and angles
- requirements and tolerances on building materials
- the ability to specify the volume of traffic
- the ability to specify how long it will last
- an estimate of the cost
- calculations that your engineers can audit and check independently or use to run simulations.

But using mathematics to specify the input, and having mathematics in the output, is not enough.

The value of mathematics

Important questions:

- What effect will the bridge have on current traffic patterns?
- How will it fare with respect to anticipated growth and changes over the coming decades?
- Should the bridge include paths and walkways to encourage more people to walk and bike, or is it more critical to meet commercial traffic needs?
- How will it affect the environment, and how should we weigh environmental concerns?
- Will the placement of the bridge benefit some residents and harm others?
- What else should you take into account?

The value of mathematics

It's not just that we need to tell AI what we want and to make sure we get it.

The point is that *we often don't know what we want*.

Sorting that out requires reasoning and deliberating, individually and with others.

Mathematics provides us with key capacities to reason and deliberate and to come to terms with things like measurements, costs, projections, causes and effects, likelihoods, and uncertainties.

The value of mathematics

This isn't just an argument for *applied mathematics*.

Mathematical ideas and abstractions guide future applications in unpredictable ways.

More importantly, pure mathematical reasoning encapsulates *values* that are important to us.

Mathematics is important, as a whole.

The value of mathematics

Being rational means not only having goals and values but also deliberating, planning, and coordinating with others to attain them.

Being able to reason about our goals and values presupposes that we can express them to ourselves and to others.

For AI to help us, our interactions have to be mediated by the rich network of concepts and ideas we use to make sense of the world, and mathematics is an essential part of that network.

Conclusions

Formalization and the digitization of mathematics opens up new opportunities for

- verification
- discovery
- exploration
- curation
- communication
- collaboration
- teaching

of mathematics.

Conclusions

Mathematics has been central not only to the scientific method, but to practical decision making in technology, economics, finance, logistics, and public policy.

The AI for mathematics movement is encouraging, since it focuses on

- mathematical concepts, statements, and proofs as outcomes, and
- neurosymbolic methods as a means to achieve them.

Conclusions

Now there are two paths we can follow.

The first involves using AI to support scientific reasoning and decision-making, improving our mathematical models and obtaining a deeper understanding of their properties.

The second involves bypassing mathematics, leaving AI to draw conclusions as it sees fit, and accepting its oracular conclusions.

Conclusions

The first path offers us new means to discover and understand phenomena that would otherwise remain opaque to us, to think and reason better, and to make better decisions.

The second path means turning our back on science, relinquishing agency over our practical decisions, and giving up a vital part of what it means to be human.

AI offers us the choice, but it cannot tell us which path to take.

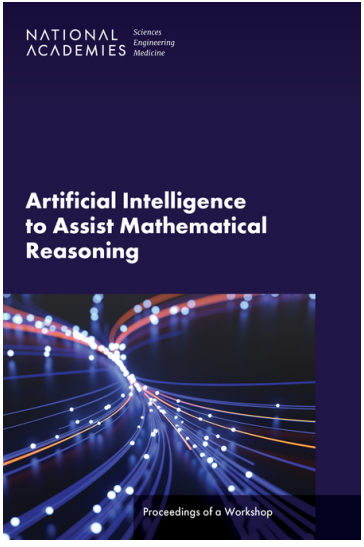
It's up to us to get it right.

AI for mathematics

Over the last few years, there has been an explosion of interest in AI for mathematics, and significant progress.

In 2023, a workshop by the National Academies for Science, Engineering, and Medicine explored the promise of new technologies for mathematical reasoning and the challenges that lie ahead.

To address these challenges, we proposed to launch a new mathematical sciences research institute at Carnegie Mellon.



NSF News

NSF invests over $74 million in 6 mathematical sciences research institutes

From improving medical care to detecting planets in other solar systems, the institutes will explore mathematical sciences with a broad range of applications

August 4, 2025

The U.S. National Science Foundation is investing over $74 million in six research institutes focused on the mathematical sciences and their broad applications in all fields of science, technology and many industries.

For over 40 years, NSF has funded Mathematical Sciences Research Institutes to serve as catalysts for U.S. research in mathematics and statistics and to produce mathematical innovations to rapidly address new and emerging challenges and opportunities. The institutes collectively investigate a wide range of mathematical research areas with potential impacts, including better patient outcomes in hospital emergency rooms, enhanced safety of semiautonomous vehicles, and detection of exoplanets using quantum physics. Previous research conducted at the institutes has had broad impacts, such as improved speed and accuracy of MRI imaging and the development of mathematical foundations of artificial intelligence-based technologies.

Institute for Computer-Aided Reasoning in Mathematics

icarm.io

Meeting the challenges

The mission of the Institute for Computer-Aided Reasoning in Mathematics is to:

- empower mathematicians to take advantage of new technologies for mathematical reasoning and keep mathematics central to everything we do;
- unite mathematicians of all kinds, computer scientists, students, and researchers to achieve that goal; and
- ensure that mathematics and the new technologies are accessible to everyone.

Empowering mathematicians

We will maintain a staff of *innovation engineers* that will:

- help mathematicians learn to use the technologies
- answer questions and provide technical support
- maintain documentation, tools, infrastructure, and other community resources
- serve as liaisons to computer science and industry
- carry out essential tasks that academics don't have time or incentives to do
- be community leaders in the use of technology
- gather resources and coordinate efforts.

Bringing us together

We will also provide:

- workshops
- summer schools
- collaborative visits
- an annual conference

These will build a community of students, researchers, mathematicians, computer scientists, engineers, and others to address the challenges together.

We need a combination of perspectives and expertise.

Ensuring access

AI and the digitization of mathematics can lead to greater democratization but it can also lead to greater inequities.

A central goal of ICARM is to ensure that all communities have the resources they need to participate in mathematics and take advantage of the new technologies.

Our original proposal included a summer school for college students, a workshop for graduate students, and an after-school program for high school students to address this challenge head on.

Status

We have been launched as a three-year pilot institute.

We are

- hiring staff and innovation engineers
- setting up infrastructure and space
- planning our first events.

Check out our web pages at **icarm.io** for more information.

Institute for Computer-Aided Reasoning in Mathematics

This is an exciting time for mathematics.

Let's make the most of it.