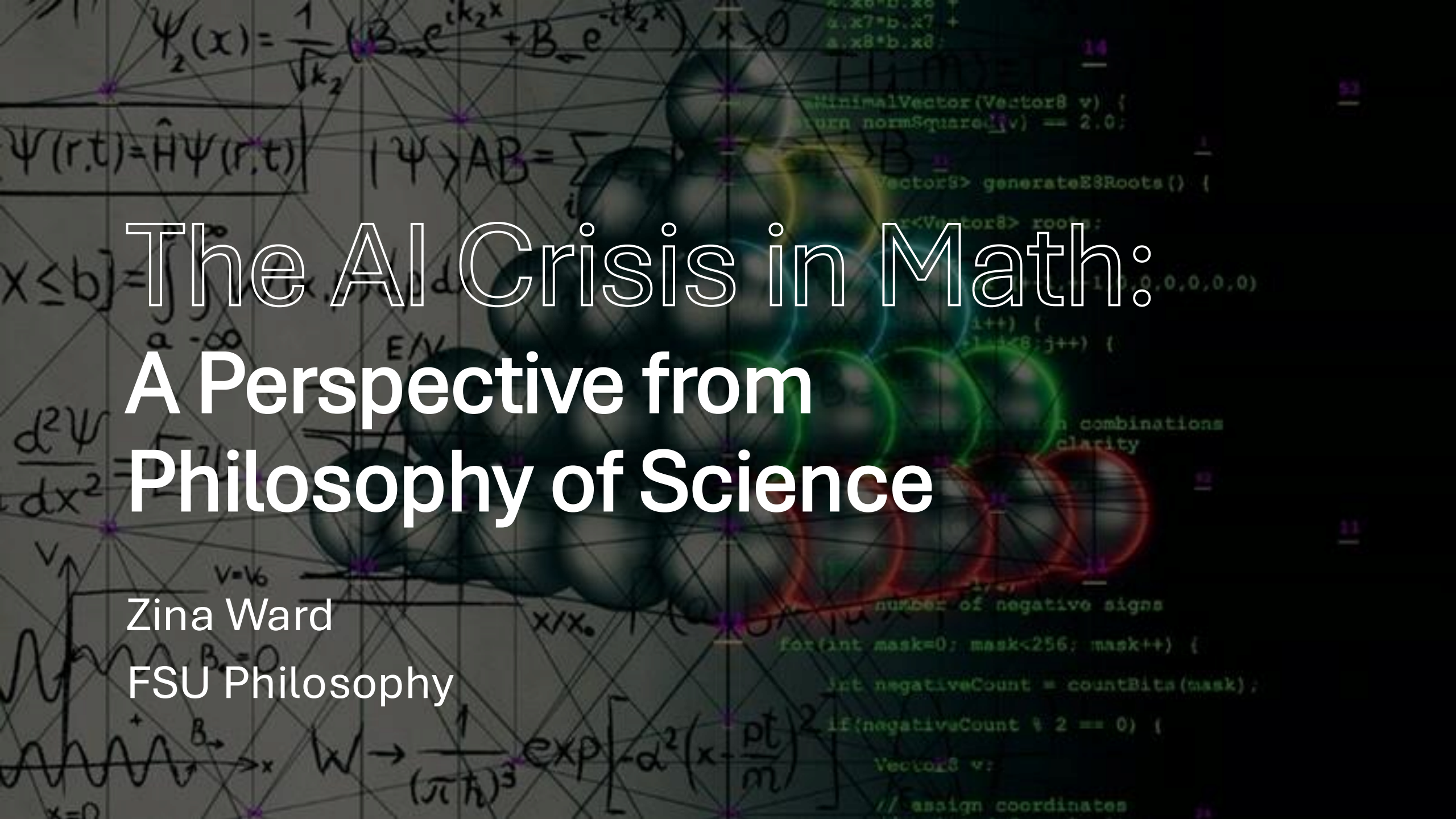




The AI Crisis in Math: A Perspective from Philosophy of Science

Zina Ward

FSU Philosophy

Why Does ChatGPT “Delve” So Much? Exploring the Sources of Lexical Overrepresentation in Large Language Models

Tom S. Juzek and Zina B. Ward*
Florida State University
tjuzek@fsu.edu, zward@fsu.edu

Abstract

Scientific English is currently undergoing rapid change, with words like “delve,” “intricate,” and “underscore” appearing far more frequently than just a few years ago. It is widely assumed that scientists’ use of large language models (LLMs) is responsible for such trends. We develop a formal, transferable method to characterize these linguistic changes. Application of our method yields 21 focal words whose increased occurrence in scientific abstracts is likely the result of LLM usage. We then pose “the puzzle of lexical overrepresentation”: *why* are such words overused by LLMs? We fail to find evidence that lexical overrepresentation is caused by model architecture, algorithm choices, or training data. To assess whether reinforcement learning from human feedback (RLHF) contributes to the overuse of focal words, we undertake comparative model testing

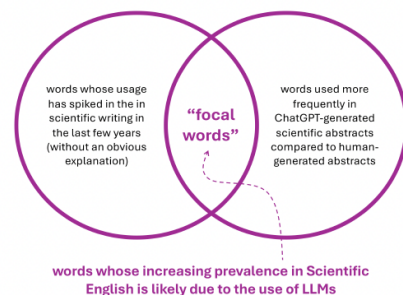


Figure 1: We formalize a procedure for identifying words whose increasing prevalence is likely the result of LLM usage. Although our focus is Scientific English, the method can be applied across domains and languages.

British Journal for the Philosophy of Science

Natural Kinds and Machine Learning: The Case of Male and Female Brains

Zina B. Ward

Neuroscientists are currently at loggerheads about whether to draw a distinction between the male brain and the female brain. The controversy is primarily rooted not in disagreement about first-order empirical results, but in conflicting assumptions about what is needed to establish a difference between two brain types. Understanding these commitments through the lens of philosophical work on natural kinds, I show that both sides of the debate adopt implausible assumptions about kindhood. Relying instead on a framework provided by cluster theories of natural kinds, I provide a philosophically and empirically motivated argument against the view that male and female brains are natural kinds. Because machine learning methods have played an increasingly important role in this debate, my argument has broader implications for the use of machine learning in science. I argue that we should not conflate supervised classification with scientific classification. Some unsupervised machine learning methods, however, might be able to help us identify natural kinds when applied with caution.

ORCID: <https://orcid.org/0000-0003-0160-6656>

PHI 5699

Data Ethics

Syllabus and Additional Course Information

Fall 2026 • 2 credits • Wednesday 12:00-1:40pm • MCH 309

Instructor Professor Zina Ward
Contact: via Canvas Inbox
Office hours: Monday 1-3pm or by appointment
Office: Dodd Hall 283

Chapter VI

Cluster Analysis and Classification

1. Statistical Tools for Classification

The practice of classification in science has been increasingly mathematized over the last century. No longer content to form groups based on qualitative observations, researchers in fields ranging from anthropology to biology to physics have come to rely on statistical tools for identifying classes of things. Cluster analysis is one family of such tools. Although clustering methods are diverse, the general problem that cluster analysis tackles can be characterized simply: “given a set of data points, partition them into a set of groups which are as similar as possible” (Aggarwal 2014, 2).¹ This remit may seem to make cluster analysis and the minimal cluster theory of kinds a natural pair. If kinds are property clusters, as the minimal cluster theory maintains, and if statistical clustering techniques aim to identify clusters of similar

RESEARCH · EDUCATION · THE MATHEMATICAL PROFESSION

Math and AI

A home for events and discussion about advances in artificial intelligence for mathematics
—and their effects on science, education, research, and the future of our profession.

Organized by [Martin Bauer](#) — Florida State University

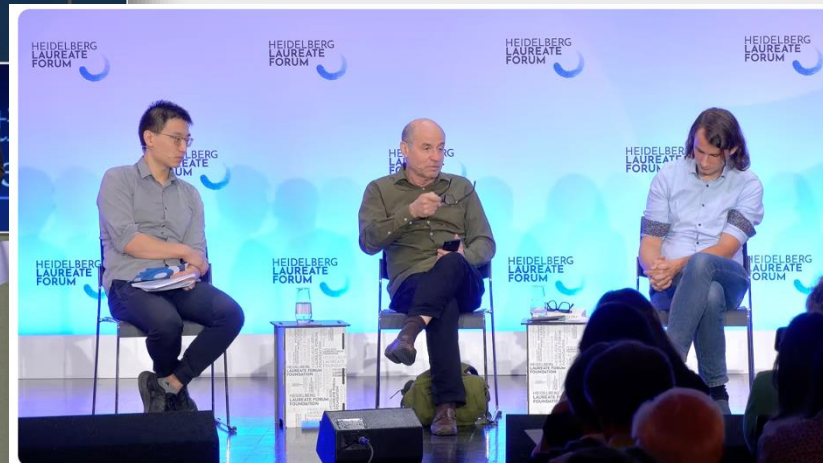
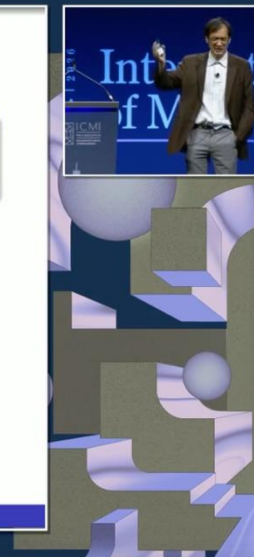
Goals and Values Question

What are the precise goals, objectives, and values of our mathematical community, and the enterprise of mathematical research?

- In the past, we largely delegated this question to the humanities, and focused instead on the technical aspects of our profession.
- Assuming the Working Hypothesis, we will no longer have this luxury.
- However, I argue that a critical examination of this question will ultimately be highly valuable, **regardless of the status of the Working Hypothesis.**

Terence Tao Mathematics in the age of AI

“historians,
philosophers,
and sociologists
of mathematics”



Panel Discussion: AI in Mathematical Research | September 15

Q: What would you say to a first year PhD student?

Michael Harris:
“...I would advise them to study philosophy...”

What is mathematics now, and what should it be?

Jeremy Avigad

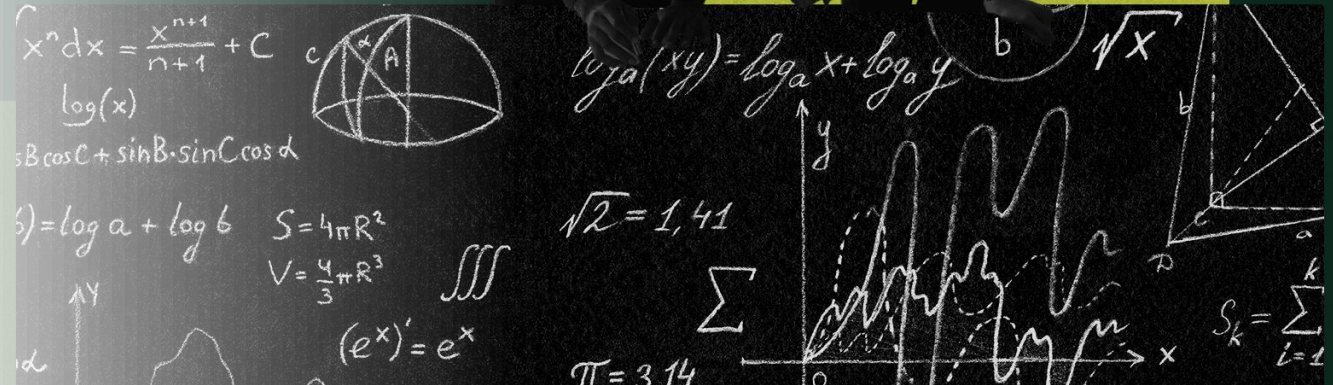
August 24, 2026

“A curious side-effect of the AI revolution is that mathematicians everywhere are being turned into philosophers, as we are forced to come to terms with our mathematical values.”

1) The Independence Thesis

2) The Credit Economy

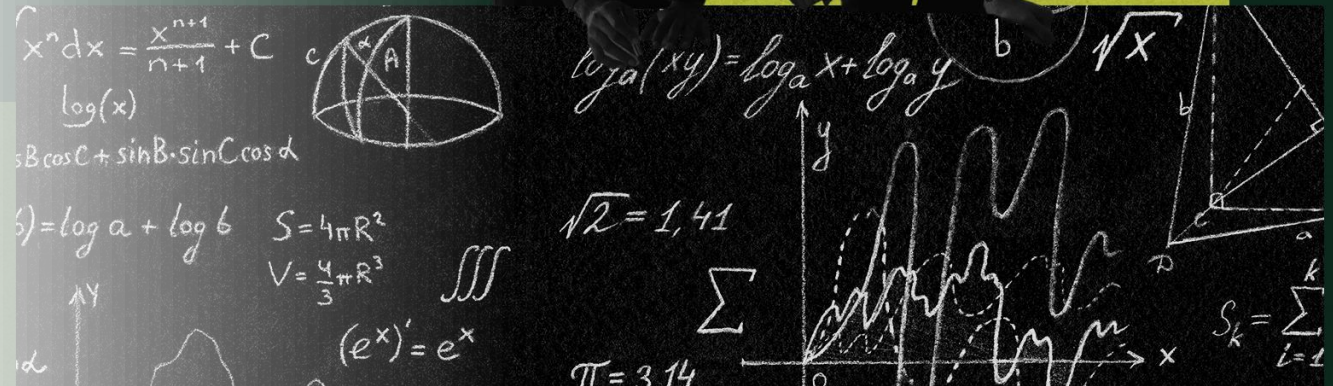
3) Mathematical Understanding



1) The Independence Thesis

2) The Credit Economy

3) Mathematical Understanding



- When is it rational for a scientist to abandon a theory?
- What criteria justify choosing one scientific theory or model over another?
- What is a rational way for a scientist to update her beliefs?



What's best (or most rational) for an *individual scientist* might not be best (or most rational) for the *scientific community*.

Not-so-hypothetical illustration

You might think it's rational for a scientist to pursue the theory or approach that is most likely to bear fruit.

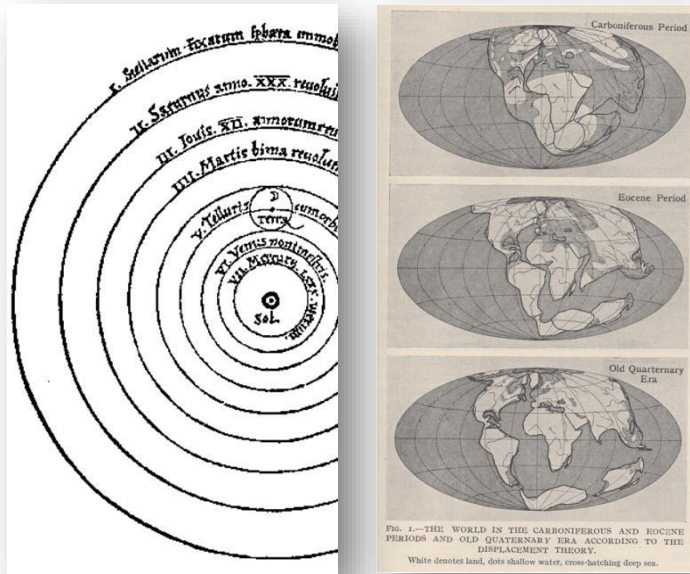
Two methods for discovering the structure of a very important molecule (VIM)

“Since all members of the community were thoroughly rational, each chemist used method I. They are still working on the problem.”

(Kitcher 1990, 11)



There are many cases from the **history of science** where we should be glad that (some) individuals were irrational.



Galileo's heliocentrism

Feyerabend (1975)

Wegener's theory of continental drift

Kitcher (1990), Solomon (1992)

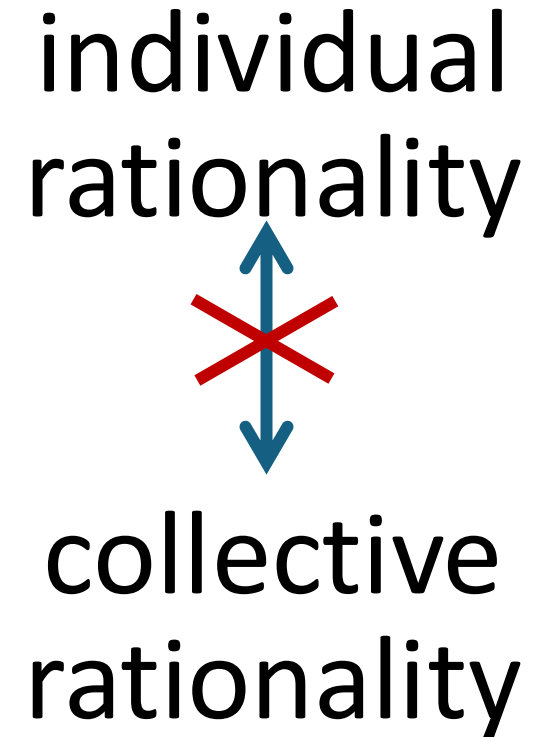
Formal social epistemology: Simple/idealized models of science show that sometimes group-level outcomes are better when some individuals behave irrationally.

Kitcher 1990, Mayo-Wilson et al. 2011, Zollman 2018

The Independence Thesis

- Epistemically **rational** individuals can form epistemically **irrational** groups.
- Epistemically **irrational** individuals can form epistemically **rational** groups.

(Mayo-Wilson et al. 2011)



Math and the Independence Thesis

The Independence Thesis applies to the social epistemology of math – perhaps increasingly so.

What is rational for individual mathematicians and what is rational for the mathematical community may be coming (further) apart.

ex. delegating challenging but solvable problems to an AI system rather than a promising graduate student

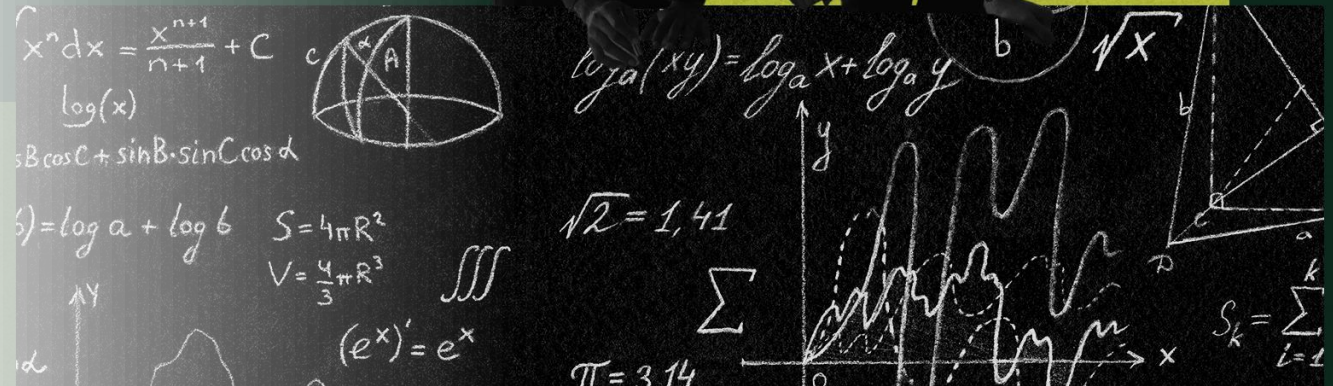
ex. homogenization effects



1) The Independence Thesis

2) The Credit Economy

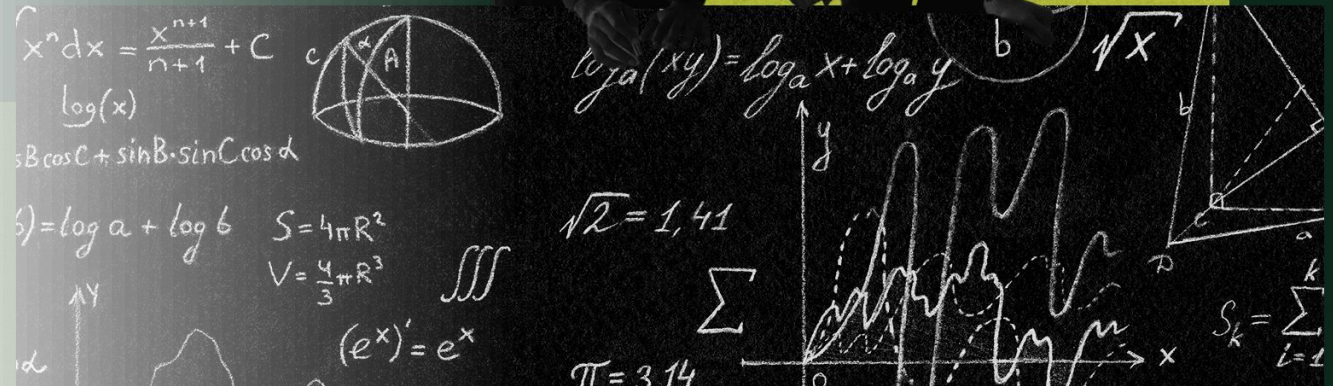
3) Mathematical Understanding



1) The Independence Thesis

2) **The Credit Economy**

3) Mathematical Understanding



Lately, in math: Skepticism about Credit



Tony Feng ✓
@tonylfeng



Second, I'm disturbed that an event which could have been celebrated as a triumph of human understanding, is instead headlined by ugly disputes.

The obsession with priority and prizes will become (much more) unhealthy in the presence of AI. My opinion is that all mathematical prizes should be abolished soon, with perhaps a gentle phaseout in the next year or two allowing only consideration of work that appeared pre June 2026. Traditional norms will have to be revisited, and egos put aside; I think the concept of individual priority and achievement will lose meaning in mathematics research, and the focus should be entirely on collective scientific understanding. This will be upsetting to many people, but I do not see how the community can proceed harmoniously otherwise.

The Credit Economy

(scientists' pursuit of recognition and prestige for their work)

Philosophical consensus: Scientists' pursuit of credit often has beneficial effects.

Scientific knowledge is (typically) a *public good* (non-excludable, non-rivalrous).

underproduced if left to the market



credit economy helps to incentivize scientific knowledge production

(Dasgupta et al. 1993)



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Zollman 2010

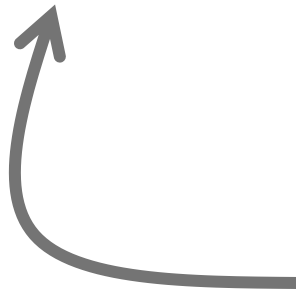
underproduced if left to *solely truth-seeking* scientists

- utility from: leisure time, joy of discovery
- joy of discovery: doesn't matter who makes the discovery

Credit Allocation

Three families of ways to allocate credit (Strevens 2003)

- 1) *Egalitarian systems*: Scientists all receive equal credit.
- 2) *Resource-based systems*: Scientists receive credit in proportion to the talent or effort they invest in their research.
- 3) *Achievement-based systems*: Scientists receive credit in proportion to actual achievements (discoveries, results, proofs, etc.).



The Priority Rule

Only the first person/team to make a discovery is given credit for it.

Merton (1979)

Benefits of the Priority Rule (Strevens 2003)

Winner-confers-all benefits

race: Only the first scientific discovery brings social benefits.

Q: What is the socially optimal reward allocation scheme?

A: The priority rule (**winner-takes-all credit**)



Other Benefits of the Credit Economy

- The priority rule helps maintain a socially beneficial *distribution of cognitive labor* among research approaches. (Kitcher 1990)
- The credit economy incentivizes open/wide *sharing of the results* of scientific work. (Heesen 2017)
- ...



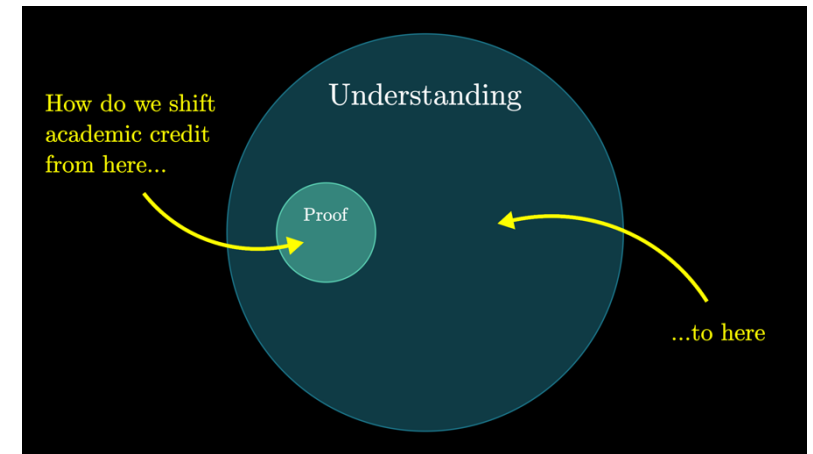
On credit in math

The credit economy in math should arguably be retained in some form. But how should it be modified?

Less radical

Change *what* credit is assigned to

- Thurston (1994): “we would be much better off recognizing and valuing a far broader range of activity”
- Tao (2026): proof digestion
- Sanderson (2026), “If math is more than proof, we need to better celebrate the rest of it”



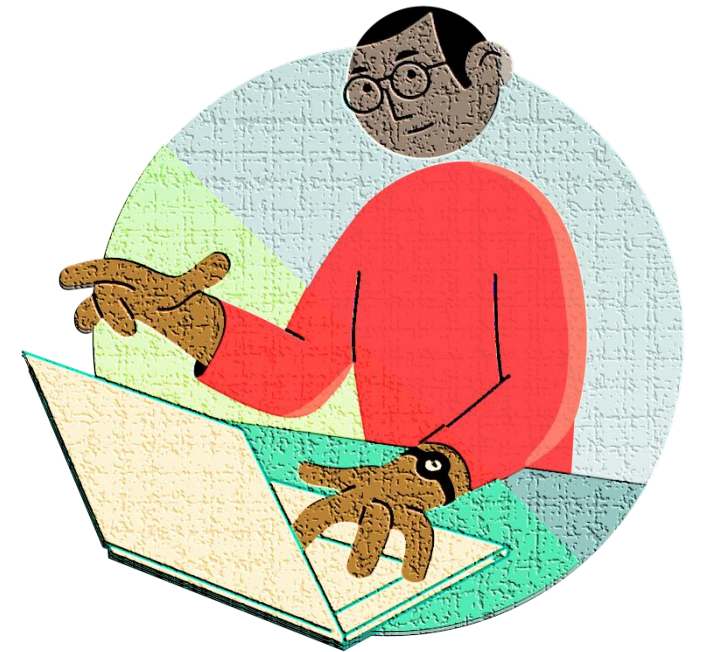
On credit in math

The credit economy in math should arguably be retained in some form. But how should it be modified?

More radical

Change *how* credit is allocated (no more priority rule)

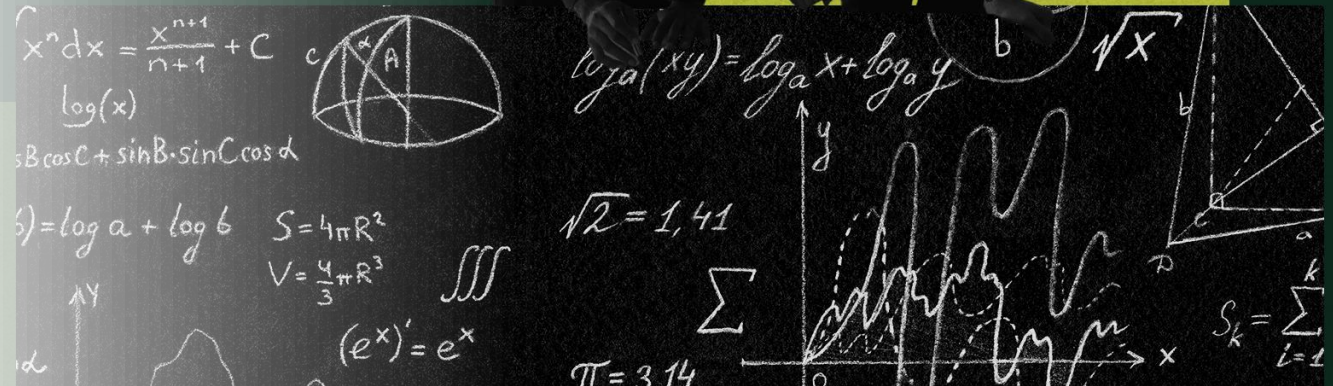
- Weinrich (2026): co-ownership of mathematical ideas after publication



1) The Independence
Thesis

2) **The Credit
Economy**

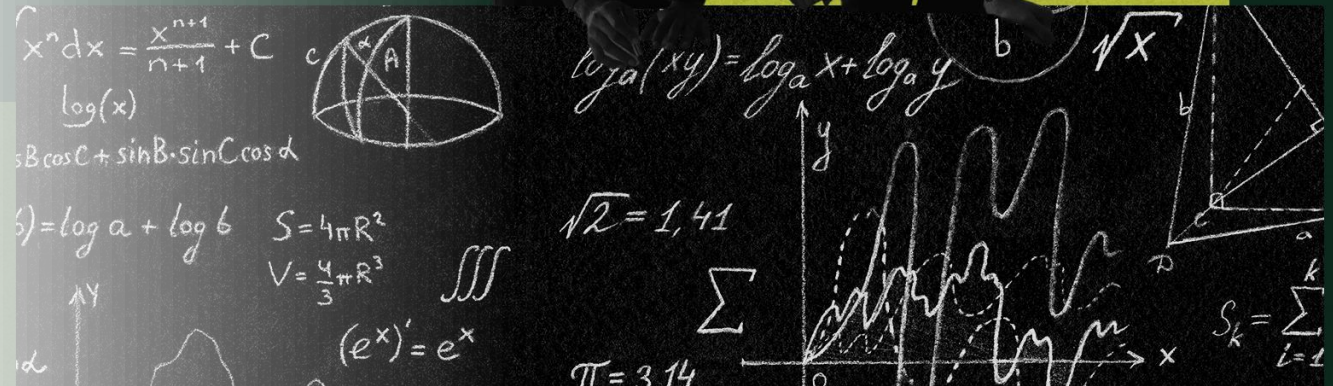
3) Mathematical
Understanding



1) The Independence
Thesis

2) The Credit
Economy

3) **Mathematical
Understanding**



APPEARED IN BULLETIN OF THE
AMERICAN MATHEMATICAL SOCIETY
Volume 30, Number 2, April 1994, Pages 161-177

ON PROOF AND PROGRESS IN MATHEMATICS

WILLIAM P. THURSTON

This essay on the nature of proof and progress in mathematics was stimulated by the article of Jaffe and Quinn, "Theoretical Mathematics: Toward a cultural synthesis of mathematics and theoretical physics". Their article raises interesting issues that mathematicians should pay more attention to, but it also perpetuates some widely held beliefs and attitudes that need to be questioned and examined.

The article had one paragraph portraying some of my work in a way that diverges from my experience, and it also diverges from the observations of people in the field whom I've discussed it with as a reality check.

After some reflection, it seemed to me that what Jaffe and Quinn wrote was an example of the phenomenon that people see what they are tuned to see. Their portrayal of my work resulted from projecting the sociology of mathematics onto a one-dimensional scale (speculation versus rigor) that ignores many basic phenom-

“We are not trying to meet some abstract production quota of definitions, theorems and proofs. The measure of our success is whether what we do enables people to **understand** and think more clearly and effectively about mathematics.”

Responsible Release of AI-Generated Mathematics

Advisory Group on Mathematics and Artificial Intelligence at IAS

29 September 2026

“[I]t is now the case that AI can output mathematical arguments in situations without the human who prompted it being able to understand the arguments, verify them, or take responsibility for them. We believe that human understanding of mathematics remains of paramount importance. How, in this new era, can we work towards a new paradigm that includes human understanding of mathematics as part of responsible scholarly output?”

What *is* mathematical understanding?

Understanding as possession of *abilities*

Avigad (2008): To understand *just is* to have certain abilities.

“Suppose I tell you that **my friend Paolo understands group theory**, and you ask me to explain what I mean. In response, I may note that Paolo can **state the definition** of a group and **provide some examples**; that he can **recognize** the additive group structure of the integers, and **characterize all the subgroups**; that he knows Lagrange’s theorem, and can **use it to show** that the order of any element of a finite group divides the order of the group; that he knows what a normal subgroup is, and **can form** a quotient group and work with it appropriately; that he **can list** all the finite groups of order less than 12, up to isomorphism...”



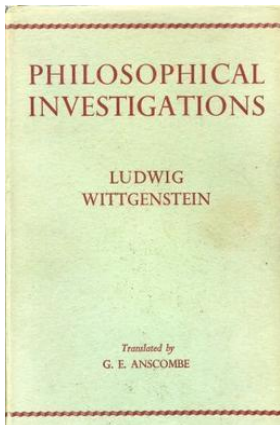


Understanding as possession of *abilities*

Avigad (2008): To understand *just is* to have certain abilities.
(really a framework, rather than a full theory of understanding)

To understand **a proof** is to possess the abilities to...

- respond to challenges as to the correctness of the proof, and fill in details and justify inferences at a skeptic's request
- indicate 'key' or novel points in the argument, and separate them from the steps that are 'straightforward'
- offer generalizations, or to suggest an interesting weakening of the conclusion that can be obtained with a corresponding weakening of the hypotheses
- provide a diagram representing some of the data in the proof, or to relate the proof to a particular diagram
- (...plus 7 more...)





Understanding as possession of *abilities*

Avigad (2008): To understand *just is* to have certain abilities.

objection: what about the *feeling* of satisfaction or the *mental states* involved?

Understanding as *unification*



“Understanding [a] phenomena is... [a matter] of seeing **connections, common patterns, in what initially appeared to be different situations.** Here the switch in conception from premise conclusion pairs to derivations proves vital. Science advances our understanding of nature by showing us how to derive descriptions of many phenomena, using the same patterns of derivation again and again, and, in demonstrating this, it teaches us how to **reduce the number of types of facts that we have to accept as ultimate (or brute).**” (Kitcher 1989, 432)

Understanding as *unification*



One type of understanding in math:

unificatory understanding (Frans 2021)



“allows one to see that mathematical statements are the result of a more general pattern and not... a collection of isolated results” (1117)

Open questions

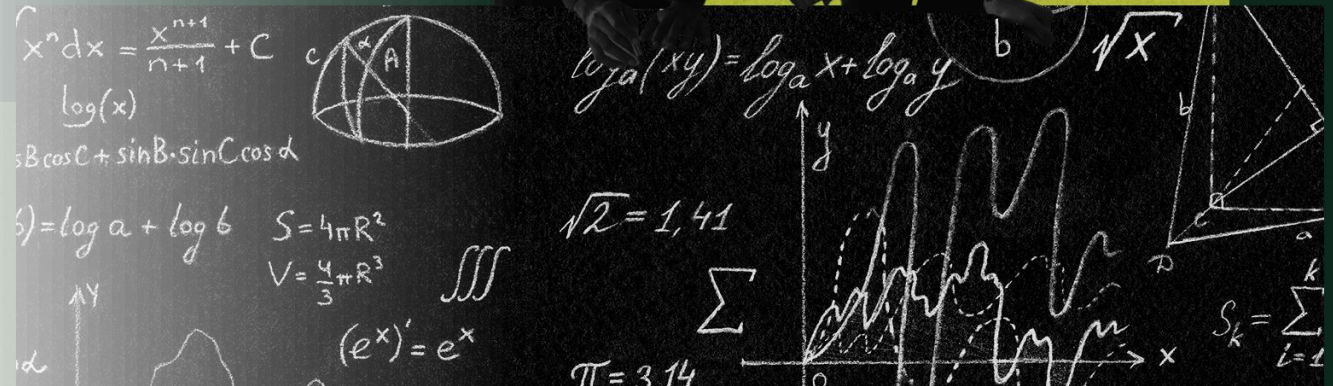
- Do abilities constitute understanding or are they just indicators of it?
- How much of the understanding mathematicians are after is unificatory understanding?
- How does understanding of proofs differ from understanding of [theorems / definitions / concepts / methods / etc.]?
- Can understanding be rewarded independently of other mathematical accomplishments?



1) The Independence
Thesis

2) The Credit
Economy

3) Mathematical
Understanding



Key References / Reading Recommendations

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The Philosophy of Mathematical Practice

First published Tue Apr 7, 2026

“Philosophy of Mathematical Practice” (PMP) refers to a broad cluster of approaches in the philosophy of mathematics. These approaches share a common focus on philosophical issues arising from actual mathematical practice. It is also characteristic of PMP to consider philosophical problems in the context of specific historical or current mathematical practices. While there have been attempts to more precisely define the notion of mathematical practice, all that needs to be understood by this, as a first approximation, is mathematics as practiced by mathematicians ranging from heuristic informal strategies to formalized developments.

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Philosophy of Mathematics

First published Tue Sep 25, 2007; substantive revision Tue Jan 25, 2022

If mathematics is regarded as a science, then the philosophy of mathematics can be regarded as a branch of the philosophy of science, next to disciplines such as the philosophy of physics and the philosophy of biology. However, because of its subject matter, the philosophy of mathematics occupies a special place in the philosophy of science. Whereas the natural sciences investigate entities that are located in space and time, it is not at all obvious that this is also the case for the objects that are studied in mathematics. In addition to that, the methods of investigation of mathematics differ markedly from the methods of investigation in the natural sciences. Whereas the latter acquire general knowledge using inductive methods, mathematical knowledge appears to be acquired in a different way: by deduction from basic principles. The status of mathematical

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Mathematical Explanation

First published Sun Apr 6, 2008; substantive revision Fri Jul 21, 2023

The philosophical analysis of mathematical explanation concerns itself with two different, although connected, areas of investigation. The first area addresses the problem of whether mathematics can play an explanatory role in the natural and social sciences. The second deals with the problem of whether mathematical explanation occurs within mathematics itself. Accordingly, this entry surveys the contributions to both areas, it shows their relevance to the history of philosophy, mathematics, and science, it articulates their connection, and points to the philosophical pay-offs to be expected by deepening our understanding of the topic.

• 1. Mathematical explanation in the empirical sciences

Thanks!

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