September 2026

Canadian Mathematical Society
Société mathématique du Canada

(Vol. 58, No. 4)

CMS NOTES de la SMC

IN THIS ISSUE

PG

01 **Cover Article**
After Leiden
— Ilia Binder

06 **Editorial**
Collaboration With Our New Robot Overlords: II
— Robert Dawson

08 **CSHPM Notes**
The Classification of Research Mathematics from 1846 to the Present
— Graig Fraiser

16 **Education Notes**
Why do students cheat – an economic approach (Part 2)
— Kseniya Garaschuk

22 Mathematics Assessment Season
— Egan J Chernoff

Book Review

26 The Sky Took Us
— Nilima Nigam

Mosaic

28 Exploring EDI: Definitions, Examples and Conjectures
— Kseniya Garaschuk



37 46 **Contributed Articles**
New Worries of an Old-Fashioned Colleague
A pictorial story — Javad Mashreghi

55 **CMS Meetings**
2027 CMS Summer Meeting,
2027 CMS Winter Meeting
2026 CMS MathEd Meeting

64 **Calls & Announcements**
Call for Nominations: 2026 CMS Excellence in Teaching Award
2027 Math Competition Grants
ICIAM Dianoia: Volume 14, Issue 3, July 2026
Books Available From Teachers College Press
StudC Fall 2026 Programming
Membership Ads

After Leiden

Cover Article

Ilia Binder (University of Toronto), *President, CMS*

In May 2026 an internal model at OpenAI produced a counterexample to a 1946 conjecture of Erdős on unit distances, a problem that had stood for eighty years. The result is real: a companion paper by external mathematicians checked it, and Gowers said he would recommend it for publication in the Annals without hesitation. Some of us were impressed and some alarmed; I was both. But it is worth being exact about what happened, because the details are the argument. The machine found the construction. Humans verified it, simplified it, and traced the ideas it rested on back to earlier work of Ellenberg, Venkatesh and others — work the model did not identify or credit; establishing that lineage remained a human scholarly task. And only months before, executives at the same company had claimed on social media that its system had solved ten of Erdős's problems, a claim withdrawn within days when it turned out to consist largely of rediscovering known results, as the mathematician who keeps that list pointed out. The triumph and the embarrassment teach the same lesson: the machine can now find real mathematics, and it cannot by itself tell you what is new, what is sound, or whose work it builds on.

A second example arrived in July, and it cuts a different way. Levent Alpöge announced a counterexample to the Jacobian conjecture, open since Keller posed it in 1939: an explicit polynomial map from C^3 to itself whose Jacobian determinant is the constant -2, and which nevertheless sends three distinct points to the same image. The conjecture is therefore false in dimension three and, by adjoining identity coordinates, in every dimension above it; the plane case remains open. The question came to him from Akhil Mathew, and the counterexample came out of a few hours of work with Anthropic's Claude Fable 5. Mathematicians checked the computation at once, and within days it had been formalized in a proof assistant and further consequences had been drawn from it.

Two features of this episode deserve our attention. The first is that anyone can check it: one computes a determinant and watches three points collide, and many mathematicians had done so within a day. A conjecture of eighty-seven years was settled in an afternoon, not because anyone trusted the machine, but because the object it produced was cheap to verify. That is a property worth wanting in a result, and worth asking for. The second is what checking does not give you. Written down, the map looks like a miracle. Terence Tao then reconstructed it: the map comes from multiplying polynomials together, and it fails to be injective because the same product can arise from different factorizations. Nothing miraculous remains — but the miracle disappeared only when a human explained it. The machine produced the example; a human supplied the reason. That division of labour may be the shape of much that is coming, and it is why the rest of this note dwells on understanding and not on certification alone

The Leiden Declaration on Artificial Intelligence and Mathematics appeared on the second of June, endorsed within a day by the International Mathematical Union. I have signed it, and I ask the Canadian Mathematical Society to take it seriously.

Its central worry is not science fiction. Present-day systems produce arguments that look like proofs and are not: fluent, plausible, and wrong in ways that are hard to see. Our literature is a building in which every floor rests on the one below, and enough cheap, widely copied errors near the foundation make it unsafe to stand in. To this the Declaration adds two further concerns. Models reproduce human results without crediting the humans who found them. And proofs generated inside proprietary systems, which academics cannot open, would hand the direction of mathematics to companies rather than to mathematicians. The remedies it proposes are modest and correct: disclose the use of AI, keep publishing in peer-reviewed journals, and require that a result be checkable without proprietary access. A proof that only a paid model can verify is not a proof the community owns.

I want to be careful here, because it is easy to be misread. The Declaration is not a complaint against the machines, and neither is this note. Several of its authors build these systems for a living. Used well, an AI is a fast and tireless assistant, and I have no wish to send it back. The question of whether mathematicians will use these tools is already settled; we do. The questions that remain are practical: under what rules, and who writes them

There is even a technology that meets the first worry head on. A proof written in a system like Lean and checked against its library, Mathlib, cannot hide a gap: the kernel accepts nothing on plausibility. To be precise, it guarantees the statement as encoded, not that we encoded the statement we meant — that check remains ours — but the merely plausible step, the kind that reads well and fails, is exactly what it refuses. It is not yet a general remedy. Most of mathematics is not formalized at all, and formalizing a serious theorem has until recently been slow work. That is changing fast, and not in a simple direction: the unit-distance disproof was formalized in Lean within a week of its announcement, at first leaning on two results not yet in the library, and within five weeks it had been formalized outright, with nothing assumed beyond the axioms — by another machine, which wrote more than a million lines of Lean in three weeks, against the two and a third million that nine years of human work put into Mathlib. Verification is becoming cheap. Whether it becomes ours or theirs is a separate question. A formal proof, moreover, can be correct and still tell you nothing about why it is true. What we need beside verification are tools that help a reader understand a proof and not merely certify it, and here the first steps exist. Patrick Massot's blueprints already turn a formalization into a human-readable document, with an automatically drawn map of how its parts depend on one another; they have served projects from Scholze's liquid tensor experiment to Tao's work on Freiman–Ruzsa. His current work aims at documents in which the reader chooses how much detail to see, from a one-line summary to the complete argument. That is a direction a society should encourage: not only an AI to be policed, but an interactive mathematics to be built.

Building that is only one of the society's tasks. The Declaration names funders, journals, institutions, societies, and for a national society these are not abstractions. The CMS publishes journals, runs meetings, awards prizes, sustains a competition pipeline, and speaks to government. It is exactly the place where a principle becomes a practice, or fails to. Signing a declaration costs nothing. Carrying it out is work, and the work is ours.

Consider teaching, which is most of what we do, and where the confusion is greatest.

Most of the students we teach will never become mathematicians. We teach calculus and linear algebra to engineers, to economists, to biologists. For years we half-justified these courses by telling students they would one day need to compute the integrals themselves. That was never quite true, and it is now plainly false: for the standard integrals we assign, freely available software is faster than our students will ever be, and usually more reliable. What is left is the reason that was always the real one. A person who cannot reason cannot check the machine, and a person who cannot check the machine is at its mercy. The service role of mathematics has not weakened. It has lost its excuse and kept its purpose, which makes it more important than before, not less.

Training mathematicians is harder, and here I have less confidence and more worry. The temptation is to answer with a list of tools — learn this proof assistant, learn to write that prompt — and to mistake the list for a plan. Tools change every few months; the mathematician we are trying to form takes years. What must be protected is the very thing the tools most threaten: the long, unpleasant, private struggle with a problem that will not yield. Mathematical maturity is not handed over in lectures. It is built in exactly those hours, and a student who gives them to a machine has bought a grade and sold an education.

Problem solving deserves its own word here, because it is the training ground for all of this. Lectures transmit definitions and theorems; only problems teach students how to begin when no one has shown them what to do. Here my background speaks: I come from the Russian tradition of mathematical circles and olympiads, in which solving problems was not a preparation for mathematics but its first form, and I have seen what that tradition produces. The useful distinction is between an exercise and a problem. An exercise asks students to repeat what they have been shown, and machines now do exercises instantly. This changes their role, not their worth: done honestly, exercises still build fluency, as scales do for a musician, but they can no longer carry the weight of mathematical formation, and a submitted exercise no longer tells us whether the student could have done it unaided. A problem gives them nothing but the question, and working through it builds the judgment, the taste and the stamina that nothing else builds. If we mean what we say about protecting the struggle, then problem seminars and circles belong at the centre of our programs, not at their margins

There is also the harder matter of keeping them at it. Students who watch a machine dispose in seconds of a problem that cost them a week may be forgiven for asking why they should bother. We owe them an honest answer, and we have one: the reward of mathematics was never that no one else could solve the problem; it is understanding, and understanding is not something a machine can have in your place. Our task is to let students feel that difference early, before discouragement hardens into departure — and not only undergraduates, since the doctoral student wondering what a thesis is for deserves the same answer. Motivation is not a soft concern; without it, nothing else we plan will matter.

And there is the calibration, which is genuinely new. Students who never touch these systems will be helpless before long; students who reach for them at the first sign of difficulty risk never building anything of their own. What we must teach is timing: struggle first and consult the machine after; use it to check and to explore, not to think in your place; notice the moment when it stops helping you think and starts thinking instead of you. They should also know that these systems are trained to be accommodating. When Tao published the record of his own session with a model while working through the Jacobian example, readers were struck by how steadily it assured him that he was right. A tool that approves of every step may harm a student's judgment more than one that occasionally errs: an error invites checking, while agreement passes unnoticed, because it is what we wished to hear. Overuse does not produce a weaker mathematician. It produces none. The Declaration says the goal of the subject is human understanding, and in the classroom that is not a slogan: it is the struggle we must refuse to automate away, even as we teach students to reach for the tool once they have done the work that makes it a tool rather than a substitute. These two demands pull against each other, and I see no clean way to satisfy both. The society will not resolve this tension. It can at least keep us honest about it.

Some of this the CMS can act on now. The most important step is also the simplest and the one most fully in our hands: require, in the Canadian Journal of Mathematics and the Society's other journals, a short statement of which AI tools an author used and where. Disclosure should be proportionate — substantive use in discovery, proof, computation or exposition is what matters, not spelling correction — and the policy should state what the Declaration takes for granted: a system cannot be an author, and responsibility for a paper rests with the humans who sign it. It costs us nothing and enacts the Declaration directly. Next, and more urgent than it sounds, we should give referees written guidance on both halves of one problem: not to upload manuscripts under review to external AI services, a confidentiality risk that journals are already confronting; and to ensure that the mathematical judgment expressed in a report is their own — help with language is one thing, delegated assessment is another. We should make it editorial policy that a published result be verifiable without proprietary access. And the Society should enter a conversation it has so far only watched: what consent and attribution ought to mean when our journals and archives become training data for proprietary systems.

In teaching our influence is only advisory, since curricula belong to departments, but nowhere are the stakes higher, and the remedy is not the same in every classroom. In proof-based courses we can move the weight back into the room: oral examination, proofs at the board, students defending their own solutions. In the large service courses this does not scale. I have taught calculus to eight hundred, and I will not be oral-examining eight hundred; there the honest answer is proctored, in-class assessment, or a frank admission that we do not yet have a clean one. A problem set done at home is now a test of the student's subscription, not of the student — it is no longer evidence of unaided work — and to pretend otherwise only teaches students that we are not paying attention. Competition mathematics, the olympiad pipeline the Society already supports, trains exactly the reasoning that has gained value, and should be funded as such.

Advocacy is the slowest of these, and here I want to be a Canadian about it. It is easy to write that the danger is dependence on three or four American companies, and there is something to that. But Canada has companies and institutions of its own: Cohere is Canadian, and Mila, the Vector Institute and CIFAR are a good part of why this country counts in the field at all. We are not bystanders to this technology, and we have some leverage over its direction; our sharpest problem is not a foreign menace but the quiet export of our best students to laboratories that pay in multiples of a professor's salary. The Society should press NSERC and the government on both fronts at once: to keep funding the training of human mathematicians, and to keep research infrastructure open and verifiable, so that the direction of the subject stays with the mathematical community rather than drifting to whoever owns the largest machines. One more point, small only in appearance: whatever policies the Society adopts must exist in both official languages, and we should notice that the models themselves are not equally capable in both. If these tools are becoming part of how mathematics is learned and done, a gap between their capabilities in French and in English is a gap in access for our francophone students and departments, and it belongs on the same list of inequities the Society already watches.

In the spirit of the Declaration I have just endorsed, I should make a disclosure: I used an AI system to criticize and edit drafts of this note; its argument and conclusions are my own.

I have no illusions about the shelf life of these pages. Given the speed of the last two years, the specifics may be stale two months after they are printed, and the whole note may read as naive in a few. But the particulars — the tools, the companies, the fixes — were always going to date. The principles will not: disclose what the machine did, keep proofs verifiable by anyone, protect the human understanding that is the point of the whole enterprise. Those I ask the Society to adopt now, together with a date for revisiting the rest. And when the revision comes and these pages look quaint, that too will be mine.

Collaboration With Our New Robot Overlords: II

Editorial

Robert Dawson *Editor, Notes*

Things are happening fast.

As you've probably heard, OpenAI has recently (September 2026) announced a resolution of one of the Clay Millennium problems, constructing a singular solution to the Navier-Stokes equations, in which well-behaved initial conditions lead to a finite-time blowup. The claimed solution is a cylindrical vortex which "implodes" to a singularity in a finite length of time. The solution has not yet been explicitly constructed, but a machine-checkable existence proof using Lean has been released.

Physically, such a result is surprising but not unprecedented. The surprise is partially because we don't see it in real life: in most cases blowups like this in physics are prevented by the breakdown of the model. For instance, while something similar happens when wind patterns on a scale of many kilometers form a small intense tornado, a tornado does not continue to intensify until infinite wind speeds are reached! Rather, other effects that were not strong enough to prevent the tornado from forming become strong enough, relatively, to limit its intensity. Similarly, as a small bubble in a fluid collapses under surface tension, the curvature grows and the collapsing force increases faster than the outward pressure from the gas trapped inside. A simplistic model suggests that the gas should heat adiabatically to an infinite temperature, and this has been proposed as a way to achieve nuclear fusion; unfortunately, the model breaks down before this can occur, though under some circumstances not until the gas in the bubble becomes white-hot. And I once saw a solution to the five-body gravitational problem in which infinite velocities are reached in a finite time. Of course, to free this unlimited kinetic energy, some of the potentials $-MiMjG/rij$ must become arbitrarily large, distances rij must approach 0, and the model breaks down when the bodies collide!

But the concern among mathematicians is not that when you stir your next cup of coffee it may develop a singularity and explode. Rather, there's concern about the way in which the research has been done. There is some suspicion that the proprietary large language model that Open AI used may have been trained (in part) on publications in which mathematicians working on the same problem published their interim results. At the time of writing, this seems to be unverified, and may be a false alarm; what seems clear is that OpenAI, using enormous resources of a type not generally available, has horned in on an established research area, in a fashion not generally accepted in the mathematical community. The result also seems to have been announced publicly without any form of peer review, another solecism.

Now, that phrase “not generally accepted” must be read with nuance. On a small self-contained problem, it is not unknown for two (or more) mathematicians to be working on the same problem at the same time, each oblivious to the other(s). This may continue to parallel publication, or an editor may suggest that the authors combine their work in a joint publication. For a large project such as the Navier-Stokes problem, it would be unlikely for established researchers to be unaware of each other: they read the same journals, attend the same conferences, and quite likely keep each other informed before they tell the rest of the community. This is expected, but it’s understood (especially in the more “accessble” areas of mathematics) that every so not-very-often an amateur or undergraduate will solve a problem that is baffling a nonempty set of experts. And that’s the luck of the game. While the suggestion has occasionally been made that mathematicians should join lawyers, engineers, and geologists in setting up a closed shop and seeking the right to prosecute any outsider who tries to practice the craft from outside the tent, the idea has not caught on; and even those supporting it are not, I think, motivated by the need to prevent the occasional outsider from inadvertent trespass on an established research project.

However, OpenAI is by no means an amateur creating proofs at their kitchen table after washing the dinner dishes. It’s estimated that the computing resources thrown at this frontal assault on the outstanding Clay Millennium Problems cost in the millions of dollars. Though of course OpenAI’s main purpose was to showcase their software, as evidenced by the selection of problems that every science journalist has heard of, it’s interesting to wonder what the result would have been if the same resources had been put into buying teaching relief for all the leading researchers in the field. Cash infusions of this scale tend to get results… as indeed was the Clay Institute’s assumption when they offered the prizes.

It may be argued that it is not new for some researchers to have access to computing resources that others don’t. When Appel and Haken used intensive computation to prove the four-colour theorem in 1976, not every graph theorist would have had access to the large amount of mainframe CPU time that their proof needed, even if they had known what to do with it, and the personal computers of the day were not adequate to the task. More recently, there have been periods when computer algebra systems were on some desks and not others. (As the great Piet Hein put it, “money’s all wrong/ and the devil decreed it/ It doesn’t belong/ to the people who need it.”) Other sciences have worse inequalities of opportunity; and we generally, if grudgingly, learn to accept the situation.

But still: is it too much to ask that a nontraditional newcomer to a community, putting resources on such a scale behind their incursion, should at least find out how things are done there and try to fit in politely?

The Classification of Research Mathematics from 1846 to the Present

CSHPM Notes

Craig Fraser(Institute for the History and Philosophy of Science and Technology, University of Toronto)

IPM Notes brings scholarly work on the history and philosophy of mathematics to the broader mathematics community. Authors are members of the Canadian Society for History and osophy of Mathematics (CSHPM). Comments and suggestions are welcome; they may be directed to the column's editors:
y Ackerberg-Hastings, independent scholar (aackerbe@verizon.net)
olas Fillion, Simon Fraser University (nfillion@sfu.ca)

Two articles nicely illustrate the range of research historians of mathematics are conducting into the history of classification and information retrieval in mathematics: Michael J. Barany's 2021 "Abstract Relations: Bibliography and the Infra-structures of Modern Mathematics" [1] and Craig Fraser's 2020 "Mathematics in Library and Review Classification Systems: An Historical Overview" [4]. The present essay provides a synopsis of the part of Fraser's article that was devoted to a study of the ideas and innovations involved in the classification of mathematical research journals and books. It complements an earlier column in CMS Notes on the library classification of mathematical books [3]. Barany's article is recommended as follow-up reading for its exploration of the wider social and political aspects of classification of mathematics since the 1920s.

Some Nineteenth-Century Background

As most readers of the Notes know, mathematics—and, indeed, all of intellectual life—changed dramatically throughout the 19th century in Europe. One of these transformations was the maturation of physics into an academic discipline, with the corresponding creation of journals, academic societies, and university departments. The mathematical level and sophistication of work in physics increased substantially as well. During the 18th century major contributors to mathematical physics were also leading mathematicians: Taylor, d'Alembert, Euler, Lagrange, Laplace, and so on. However, by the end of the 19th century the leading contributors to mathematical physics were physicists: Maxwell, Kelvin, Hertz, Weber, Boltzmann, and so on. The situation is aptly summarized by McCormmach and Jungnickel [6, p. 185]: "The position of intermediary between mathematics and physics, as Riemann was seen to hold, was increasingly taken over by a new kind of specialist, the theoretical physicist. The theoretical physicist might consult or even collaborate with a mathematician, but he always worked as a physicist rather than a mathematician." This state of affairs would have implications for those who attempted to describe the research being done in physics.

Meanwhile, within mathematics itself, growing emphasis was placed on pure mathematics, a development that was connected in the case of Germany with the cultural outlook of neo–humanism (see [8]). Mathematics journals continued to include mechanics and applied topics, but over time applications received a decreasing share of the total content published in these periodicals.

Another change was the emergence of the foundations of mathematics as a field of discussion and investigation. This development was connected to the focus on pure mathematics but was also stimulated by an infusion of interest into formal logic. Traditionally, mathematics had been distinguished from the language fields of logic, rhetoric, and grammar, a distinction that was built into the structure of both the liberal arts curriculum and Enlightenment conceptions of knowledge. The emergence of formal logical systems provided a language to explore subjects in mathematics. In the philosophy of mathematics, a key work was Gottlob Frege's 1884 Die Grundlagen der Arithmetik (Foundations of Arithmetic). Frege reasoned that the basis of number in language conferred upon arithmetic an objectivity that was independent of physical considerations. It should be noted that the consolidation of foundations into a field of mathematical research did not occur immediately; rather, it was a development that only achieved full expression in the 20th century. (For more details on the subject of this section see [2].)

Describing an Expanded Discipline

The remarkable growth of mathematics in the 19th century gave rise to a genre of writing devoted to surveys of the state of work in various subjects of interest. For example, reports delivered at the annual meetings of the British Association for the Advancement of Science (BAAS) provided information about current explorations, such as Arthur Cayley's "Report on the recent progress of theoretical dynamics," which was presented in 1847 to the BAAS meeting in Dublin and published in the following year. Cayley outlined in some detail developments since 1800 involving Hamilton-Jacobi theory and the theory of canonical transformations. In 1861 Isaac Todhunter published his A History of the Progress of the Calculus of Variations during the Nineteenth Century. The word "progress" in the title indicated that the book covered work up to the time of publication and thus was as much a literature review as it was a history.

At the same time, mathematics journals demonstrated a consistency in their approaches to organizing mathematical knowledge. The general conception was outlined by Auguste Comte and André-Marie Ampère early in the 19th century. Their views were reflected in the table of contents of the inaugural publication in 1836 of Journal für die reine und angewandte Mathematik (Journal for Pure and Applied Mathematics, also known as Crelle's journal after its principal editor Leopold Crelle). The table of contents consisted of two parts: pure mathematics, encompassing analysis, geometry, and mechanics; and applied mathematics, containing parts of physics such as machines, optics, astronomy, and so on. Analysis itself was made up of arithmetic, algebra, and calculus-related parts of mathematics.

In 1871 two Berlin gymnasium teachers of mathematics, Carl Ohrtmann and Felix Müller, founded the reviewing periodical Jahrbuch über die Fortschritte (Yearbook on the Progress of Mathematics) der Mathematik. The Jahrbuch was modelled after an abstracting journal for physics that had been in existence for close to 25 years, the Fortschritte der Physik (Progress in Physics). Although the publications reviewed in the Jahrbuch consisted mainly of periodical literature, books were also included. The general organization of mathematics in the Jahrbuch reflected the subject organization of prominent research journals such as Crelle's journal. This subject ordering, arithmetic–algebra–analysis–geometry, differed from the one widely in place in library book classification, which used the more traditional ordering of arithmetic–algebra–geometry–calculus. That the most abstract and abstruse areas of higher analysis were placed before elementary Euclidean geometry reflected a "modern" orientation of mathematics that has remained in place since the second half of the 19th century. (The place of abstract structural mathematics and subject organization is examined by Barany in [1].)

Zentralblatt and Mathematical Reviews

Over the years, a substantial delay developed between the publication of articles and books and the appearance of their reviews in the Jahrbuch. By the late 1920s, this delay had grown to around seven years. In 1931, Göttingen mathematicians Otto Neugebauer and Richard Courant founded the Zentralblatt für Mathematik und ihre Grenzgebiete (Journal of Mathematics and Related Fields) to achieve a timelier review of the mathematical literature. The first editor of the Zentralblatt was Neugebauer, who retained this position until 1938, when he resigned and joined the exodus of scientists from Hitler's Germany to the United States.

On his arrival in America, Neugebauer became a professor at Brown University in Providence, Rhode Island, where, in 1940, the abstracting periodical Mathematical Reviews (hereafter MR) came into existence (on the early history of MR, as well as developments to the 1980s, see [7]). The rise of the United States as a scientific center and the sheer size of the anglophone mathematics community in the United States and the British Commonwealth made the creation of MR a natural step. The influence of Nazi policies on the operation of Zentralblatt was also a factor. Neugebauer and the Russian-American analyst Jacob Tamarkin became the first editors of the journal. In 1965, MR moved to Ann Arbor, Michigan (adjacent to the University of Michigan), where it remains to this day.

The subject organization of the Jahrbuch, Zentralblatt, and MR was similar, as is seen in the table of contents from the initial issue of each journal given in Table 1.

***Jahrbuch über die Forschritte der Mathematik* (1871)**	***Zentralblatt für Mathematik* (1931)**	***Mathematical Reviews* (1940)**
History and philosophy	Foundations and philosophy	History and foundations
Algebra and number theory	History	Algebra and number theory (including groups)
Probability and combinatorics	Algebra and number theory	Analysis
Series	Theory of sets and real functions	Topology
Differential and integral calculus	Analysis	Geometry
Theory of functions	Numerical and graphical methods	Numerical and graphical methods
Pure, elementary, and synthetic geometry	Geometry	Mechanics
Analytical geometry	Mechanics	Mathematical physics
Mechanics	Mathematical physics	
Mathematical physics and astronomy		

Table 1. The subject classification adopted by MR in 1940 was somewhat more detailed than the schematic overview presented above. The full table of the contents set forth for the first issue in 1940 of MR is given in Figure 1.

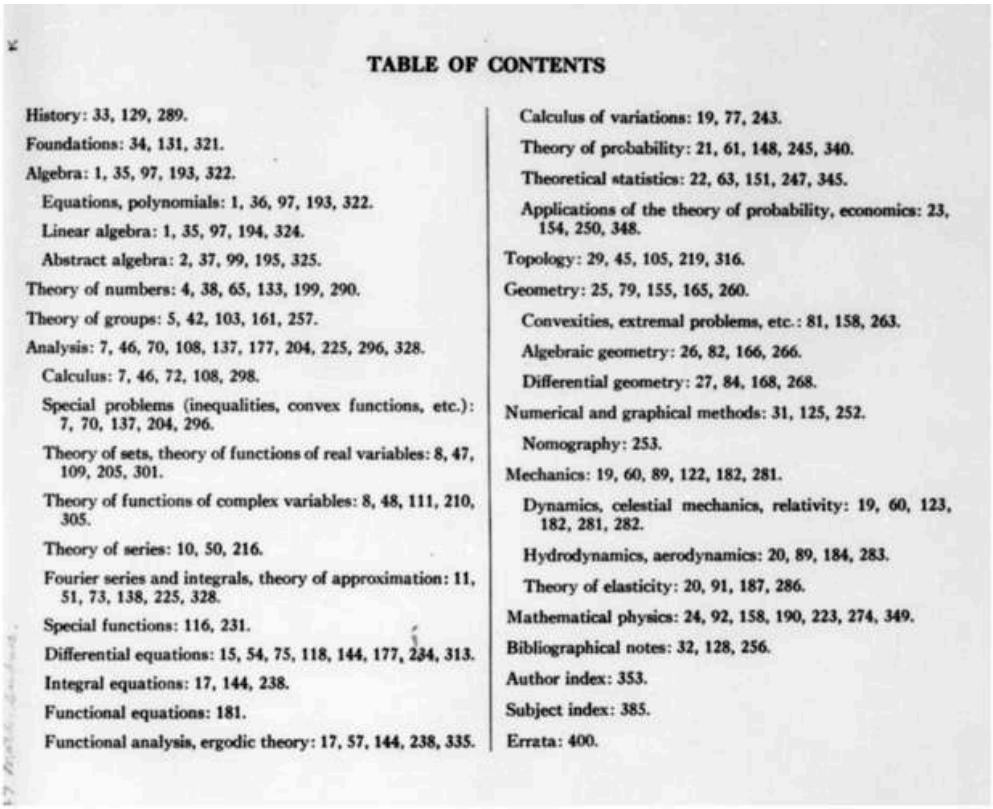


TABLE OF CONTENTS

History: 33, 129, 289.
Foundations: 34, 131, 321.
Algebra: 1, 35, 97, 193, 322.
Equations, polynomials: 1, 36, 97, 193, 322.
Linear algebra: 1, 35, 97, 194, 324.
Abstract algebra: 2, 37, 99, 195, 325.
Theory of numbers: 4, 38, 65, 133, 199, 290.
Theory of groups: 5, 42, 103, 161, 257.
Analysis: 7, 46, 70, 108, 137, 177, 204, 225, 296, 328.
Calculus: 7, 46, 72, 108, 298.
Special problems (inequalities, convex functions, etc.): 7, 70, 137, 204, 296.
Theory of sets, theory of functions of real variables: 8, 47, 109, 205, 301.
Theory of functions of complex variables: 8, 48, 111, 210, 305.
Theory of series: 10, 50, 216.
Fourier series and integrals, theory of approximation: 11, 51, 73, 138, 225, 328.
Special functions: 116, 231.
Differential equations: 15, 54, 75, 118, 144, 177, 234, 313.
Integral equations: 17, 144, 238.
Functional equations: 181.
Functional analysis, ergodic theory: 17, 57, 144, 238, 335.
Calculus of variations: 19, 77, 243.
Theory of probability: 21, 61, 148, 245, 340.
Theoretical statistics: 22, 63, 151, 247, 345.
Applications of the theory of probability, economics: 23, 154, 250, 348.
Topology: 29, 45, 105, 219, 316.
Geometry: 25, 79, 155, 165, 260.
Convexities, extremal problems, etc.: 81, 158, 263.
Algebraic geometry: 26, 82, 166, 266.
Differential geometry: 27, 84, 168, 268.
Numerical and graphical methods: 31, 125, 252.
Nomography: 253.
Mechanics: 19, 60, 89, 122, 182, 281.
Dynamics, celestial mechanics, relativity: 19, 60, 123, 182, 281, 282.
Hydrodynamics, aerodynamics: 20, 89, 184, 283.
Theory of elasticity: 20, 91, 187, 286.
Mathematical physics: 24, 92, 158, 190, 223, 274, 349.
Bibliographical notes: 32, 128, 256.
Author index: 353.
Subject index: 385.
Errata: 400.

Figure 1. Mathematical Reviews Table of Contents for Volume 1, as shown in the Internet Archive. The complete first number from January 1940 is also available for perusal.

The Mathematical Subject Classification (MSC) System

Over the first two decades of its existence the subject index volumes for MR were organized according to the subject areas listed in the table of contents of each issue. However, in contrast to the ordering in the table of contents, the index ordering was alphabetical; all subclasses were also listed alphabetically. In 1960 a system of codes was introduced in the index, in which the subject areas as listed in the table of contents were given two-digit numbers selected from 02 to 99. Before volume year 1959, all subjects in the index were listed alphabetically. By contrast, the index for 1959 listed subjects by their place in the table of contents in terms of these numerically increasing two-digit codes, according to some conception of the natural relationships that existed among these subjects.

The introduction in 1970 of the Mathematics Subject Classification (MSC) was not motivated by any particular interest in classifying the contents of MR. A reader of an issue of MR could simply consult the table of contents and go to the subject section corresponding to their area of mathematical interest. Rather, it was in order to efficiently process requests for offprints or titles that it proved useful to have a formal system of classificatory codes. The impetus to develop the MSC thus came in the late 1960s from the AMS's Mathematical Offprint Service (MOS) and its successor, the Mathematical Title Service (MTS).

In the 1970 MSC scheme, the number of classes and sub-classes increased from 900 to 1,900. The scheme maintained the subject whole numbers, but it added a letter of the alphabet to indicate a class. Further topic divisions within this class were indicated by a two-digit number. For example, representation theory of symmetric groups now received the code 20C30. Here 20—as before—was the subject area of group theory, C indicated representation theory of finite groups, and 30 was for representation of symmetric groups.

Two-digit MSC codes appeared for the first time in the table of contents of the issues of MR for 1977. They also appeared beside each subject heading and at the top of every page. During this period, three-digit codes (two-digit subject number and class letter) were employed in the AMS's periodical Current Mathematical Publications. In 1980, two-digit subject codes were provided for each review in regular issues of MR and became a more integral part of the journal. By the 1990s, every review in MR was accompanied by its full five-symbol MSC code, according to the latest version of the MSC at the time of publication.

The Arrival of MathSciNet and zbMath

The online version of MR, MathSciNet, was established in 1996. It has since replaced the printed edition, which was discontinued in 2012. (For technical matters related to the creation of MathSciNet and the platform for its application see [5].) From the founding of MR to the advent of MathSciNet, shifts in classification have occurred. The policy of MathSciNet is "historical," meaning that it designates the code that was in place at the time the abstracted item was published (for items published before 1960, the 1960 numerical codes are given). We consider here the example of set theory. In the 1940s and early 1950s, set theory was included in the subject heading "Theory of sets, theory of functions of a real variable" and in MathSciNet publications from this time period are assigned the code 27.2. In the 1950s set theory was put under "Foundations" and in MathSciNet these works are classified with the code 02, which was introduced in 1960 for foundations. Between 1959 and 1999 set theory received its own subject heading and thus in MathSciNet is given the 1960 code 04.

In MSC2000, mathematical logic and foundations were given the code 03; 02 and 04 were abolished; and set theory was returned to logic and foundations and assigned the code 03E. For instance, in MathSciNet, Abraham A. Fraenkel's Einleitung in die Mengenlehre (Introduction to Set Theory, 1946) is given the code 27.2, Abraham A. Fraenkel and Yehoshua Bar-Hillel's Foundations of Set Theory (1958) has the code 02, Nicolas Bourbaki's Elements of Mathematics: Theory of Sets (1968) has the code 04, and John P. Burgess's Set Theory (2001) has the code 03E, the latter being the subject code for set theory in MSC2000 and the current code for set theory in MathSciNet.

Similarly, the journal Zentralblatt has been replaced by the electronic reviewing service zbMath. For several decades, the agencies MathSciNet and zbMath have worked together in revising the MSC classification system [7]. Major revisions occurred in 1991, 2000, 2010, and 2020. As more book literature appears only in electronic form, the traditional call number classification systems of the Library of Congress and Dewey Decimal will decrease in importance. Instead, the MSC has moved beyond its initial utility in title-retrieval to become the dominant system worldwide today for classifying mathematics.

References

[1] Barany, Michael J. (2021) Abstract Relations: Bibliography and the Infra–structures of Modern Mathematics. Synthese 198 (Suppl 26), S6277–S6290. The supplement is titled "Enabling Mathematical Cultures."
[2] Fraser, Craig. (2002) Mathematics. In The History of Modern Science and Mathematics, edited by Brian S. Baigrie, i:305–327. Charles Scribner's Sons.
[3] Fraser, Craig. (2017) Mathematics in Library Subject Classification Systems. In Research in History and Philosophy of Mathematics: The CSHPM 2016 Annual Meeting in Calgary, Alberta, edited by Maria Zack and Dirk Schlimm, 181–197. Cham, Switzerland: Springer International Publishing.
[4] Fraser, Craig. (2020) Mathematics in Library and Review Classification Systems: An Historical Overview. Knowledge Organization 47, 334–356.

[5] Gala, Lauren, Jeffra Diane Bussmann, and Anya C. Bartelmann. (2019) MathSciNet: A Comparative Analysis of American Mathematical Society and EBSCO Platforms. Journal of Electronic Resources Librarianship 31, 1–13.

[6] Jungnickel, Christa, and Russell McCormmach. (1986) Intellectual Mastery of Nature. Theoretical Physics from Ohm to Einstein, Volume 1: The Torch of Mathematics, 1800 to 1870. Chicago: University of Chicago Press.

[7] Pitcher, Everett. (1988) Mathematical Reviews. In Pitcher's A History of the Second Fifty Years, American Mathematical Society, 1939–1988, 69–89. American Mathematical Society Centennial Publications, Vol. 1. Providence, RI: American Mathematical Society.

[8] Pyenson, Lewis. (1983) Neohumanism and the Persistence of Pure Mathematics in Wilhelmian Germany. Memoirs of the American Philosophical Society, Vol. 150. Philadelphia: American Philosophical Society.

Craig Fraser is professor emeritus at the Institute for the History and Philosophy of Science and Technology of the University of Toronto. His work on the history of mathematics and astronomy from the early 1980s to the present (including the three publications listed in the references above) can be accessed at https://cfraser.artsci.utoronto.ca/publications.htm.

Why do students cheat – an economic approach (Part 2).

Education Notes

Kseniya Garaschuk (University of the Fraser Valley)


Notes Contributing Editor, CRUX Editor-in-Chief & Chair of Equity, Diversity and Inclusiveness Committee

Education Notes bring mathematical and educational ideas forth to the CMS readership in a manner that promotes discussion of relevant topics including research, activities, issues, and noteworthy news items. Comments, suggestions, and submissions are welcome.

Kseniya Garaschuk, University of the Fraser Valley (kseniya.garaschuk@ufv.ca)

I had a few requests for Part 2 of the piece, so here we go. Now, a small disclaimer. In what follows, I provide some examples from my practice to highlight each category. I do not claim that any of these ideas are original or mind-bogglingly inventive, but those are the ideas that work for me. If you find any of these useful – drop me a line!

Quick recap: in Part 1 of this article [1], I introduced an idea of thinking about students' academic misconduct motivations through the lens of economic fraud theory. This highlights that cheating of any sort is a rational decision driven by one (or more) of the following three factors: pressure or necessity ("Do I need to cheat?"), opportunity ("Is it easy to cheat?") and rationalization ("Is it ok to cheat?"). I also gave some quick bullet points on how we as instructors can affect our students' behaviours by addressing these factors. Here, I will go deeper in each category and give a few more extensive examples from my practice.

As instructors, we are the conductors of our students' course experiences. So consider your approach to course administration and instruction and ask yourself: when do you put students, intentionally or not, in each of the three above situations?

Address Pressure/Necessity – make honest success feel achievable

When do we, as instructors, participate in the creation of the circumstances of perceived "need" to cheat? In my experience, pressure is most often associated with two common factors. The first one is high-stakes assessments where the impact of failure is significant. This can be addressed by frequent "bite-sized" quizzes instead of heavily-weighted tests or even one final exam that accounts for the majority of the course grade. Of course many of us work in departments with policies on minimal final exam weight making it de facto high-stakes and many of us will argue that having one comprehensive piece of assessment is, in fact, necessary. The approach here then is to provide enough practice through the feedback loop with low-stakes assessments throughout the term to ensure that students do not view the final exam as the insurmountable grade-changing barrier. Low stakes assessments act as fire drills in that they allow students to assess their skills and prepare them to perform under pressure before it really counts. At least that's the goal to strive towards.

The second pressure point is associated with an overly strict course structure that does not accommodate for life events such as sickness or unexpected circumstance. The rigidity of the structures, such as deadlines, has two sides. I will be the first to say that deadlines are important to keep students on track and on pace, but I will also give 1-2 day extensions on basically anything if requested in advance (longer extensions will be more carefully considered on a case-by-case basis). If the same student comes back with the multiple requests for the epsilon-extensions, we will have a chat, but that rarely happens. Finally, for my low-stakes assessment, I drop the lowest one without excuses – out of 13 weekly quizzes, I only take 12 to count toward the grade. Not only do I believe it is sensible to assume everyone should be allowed a week to not be at their top performance, but also knowing there is a drop-lowest policy can reduce panic-induced cheating. Small extensions or drop-lowest policies do not weaken structure; they make it livable.

Another important case that speaks to the necessity clause is when students feel that the assessment is misaligned with learning. If the term project is not related to the course examples, if the quiz questions differ in format and expectations from the assigned practice problems, if you claim you value explanations but your tests are all multiple choice, then students might legitimately feel the pressure to cheat since they perceive that there were not given the tools to practice the skills necessary for honest success. But let's be clear – sometimes the assessment is aligned with practice but students do not perceive it as such. I have one proven method to break this misunderstanding: I use an "aftermath" (ha!) assignment to review the test once it has been graded and returned. In part 1, for each question on the test, students have to identify sources in our course materials where similar problems or problems focusing on the same concepts appear: this could be the relevant lecture (I use skeleton slides, so the students can provide a page number), textbook section, online assignment, quiz, additional problem set, etc. Many students are surprised to discover that even the questions they thought were unfamiliar actually came from examples they have seen before. This helps them notice those connections and reinforce the value of active review and practice. For part 2, I range the activities – last term, I asked the students to review and characterize their mistakes, write on what worked well during the test prep and what changes they will make for the remainder of the term. Aftermath assignments are always eye-opening and allow students to adjust their learning strategies as well as react differently to their mistakes.

Students usually see in-term tests only as assessments, while I try my best to make them into learning experiences. One model that I've used successfully in classes from 30 to 200 students are so-called two-stage assessments, where students first complete and turn in the questions individually and then, working in small groups, answer the same questions again. For a full description of the activity see my piece [2] or my two published works [3, 4] on learning gains and student perceptions. The conclusion is clear – students love this format. Even if there are no statistically significant learning gains, this format takes the stress factor away from test taking and re-directs the experience from viewing assessments as summative to seeing them as formative.

Finally, normalize help-seeking and accommodate for it. Many first-year students do not know what office hours are and how to utilize them. This is the standard "expert-blindness": we use words such as "office hours" but we never define the term. While we believe we have an open door policy, our students simply don't have neither the experience nor courage to come ask for help from the exact same person who will be later evaluating their course performance. Moreover, with our students' busy schedules, your set office hour times might simply not work for many – offer a few options in the beginning of the course in order to find the most accommodating ones, use a bookmytime app or its equivalent to allow students to book drop-in times. Many institutions now also have some version of a Math Help Center staffed with tutors, but just knowing about its existence isn't enough. Talk about the available help in class in terms of its format, purpose and specifics of how to use it so that its availability and utility is clear.

Address Opportunity – make dishonest attempts harder

This is mostly about prevention. Individualised assessments (or at least multiple versions of the same assessment, be it a quiz or a homework) are a great approach – having 2-3 versions of the same question means students have to at least understand the procedure before copying someone's work so they can match their numbers to it. Even better if you go with same-ish but not identical questions. Next up, assignments or projects used by instructors term-to-term. Reusing an assignment or test without changing it is like leaving your house key under the doormat: convenient for you, but eventually someone is going to find it and let themselves in. I must admit, I have a couple of my absolute favourite term projects I have developed and it is incredibly annoying that I can't re-use them as take-home assignments because I know they can be found online. But I do re-use the problems – instead of assigning them as take-home projects where students will certainly google them, I use them for in-class explorations. This way the problems still get to live out their best lives in my courses without tempting my students to copy their answers.

A word on authentic problems and their sources. I draw inspiration from many sources when it comes to getting context ideas for my authentic applications. I also vary the subject matter. I have developed applications on lake sedimentation, volume of Einstein's brain, crows' feeding patterns, West Nile virus spread and much much more (not to mention everyone's favourite – Yellowstone wolves and elks). But many of my ideas come from students themselves. My favourite end-of-term assignment is to ask students to write a final exam question, including a complete and comprehensive solution. I provide structure and guidance around what it means: specifically, the problem must be an application and the context must either be plausibly constructed or grounded in real data (and I provide examples of databases worth exploring). The pedagogical benefits are substantial: students must decide what is actually important in the course. If they are to test a concept, they must first identify it as something worth testing; they must determine how it can be tested; they must choose parameters that make sense mathematically and contextually; they must ensure that the problem statement is clear and complete; they must ensure the problem is solvable. They discover very quickly that writing a good problem is much more difficult than solving one and that realization alone is transformative. This assignment also quietly communicates the fact that math is a creative human endeavour and then can participate in that creation. As an added strategic benefit, I compile all the submissions together into one monster final exam practice package, solutions and all. How do I encourage them to read it? I let them know that a modified version of one of the problems will be included in the final exam. I genuinely look forward to marking this assignment as it is one of the rare assessment moments where students' intellectual personalities surface. When they try, they really try and their curiosity, humour, disciplinary and personal interests and skills come through in ways that routine problem sets are simply not designed for. Feeding this back into my practice, student submissions provide me with rich and interesting applications rooted in real-life scenarios (and yes, Minecraft is also real-life) – ones I have drawn many inspirations from throughout the years.

I cannot not mention that oral/live or recorded presentations or exams are a great way to avoid opportunistic misconduct. A word of warning: these must be well structured and well done to ensure clear expectations and no bias in the evaluation. This is a whole other topic for discussion – maybe I will try to persuade a colleague with a lot of experience in this area to write a piece.

One trick of the trade here is whenever I catch suspected plagiarism on, for example, a quiz, I let the entire class know that there was suspected misconduct (without naming names, of course) and the quiz will not be released to anyone until the investigation is complete. Not only now does the whole class know that I do not let things slide, the suspected offender also feels the burden of negatively affecting the course experience of their peer

Address Rationalization – make cheating psychologically inconsistent with students' self-image

As instructors, we cannot eliminate every frustration students experience. Sometimes workloads do feel overwhelming. Sometimes institutional systems are imperfect. Sometimes our teaching misses students in ways we did not intend. We have to fight these rationalizations directly rather than pretending they do not exist. To be clear, none of what I do removes personal responsibility: students remain responsible for their choices. Rationalization helps create conditions where misconduct feels psychologically acceptable and my role is to attempt to dismantle those rationalizations. Not by moralizing though.

On the one hand, rationalisation is about communication and self-image. As much as possible, I explain why various assignments and assessments are designed the way they are and how it connects to the students and also to their future professional work — even if only loosely. Students are often motivated by wanting to be seen as competent and trustworthy as a professional in their chosen field, so frame integrity as part of professional identity.

I also fight incessantly against the common "in math, only the answer matters" explaining that in real-life you will inevitably have to provide justification for your decisions. And I model what I preach: I continuously remind students that I will mark their solutions, not their answers, and I do. This works both ways though – you wrote an answer with no justification, that's a 0 because an unsupported answer is functionally indistinguishable from a guess. The questions on my assignments and tests require full explanations. I assess not only whether a solution arrives at the correct conclusion, but also the depth of reasoning and clarity of communication behind it (including following through logic made messy by a careless arithmetic mistake).

But another point here is subtle – it's relationship and trust. Many students think I think of them as just numbers and funnily enough I think many of them think of me as a number. After all, I am one of the many profs they will see across 40+ courses. By far, my best course experiences as instructor are associated with the strongest bonds I built with students in those groups by learning about their lives outside of my classrooms walls. And what you get as a relevant bonus is better integrity – it is hard to justify cheating in a class where you respect and have a meaningful human connection with the prof. Building relationships comes from dozens of small interactions that communicate to students that they are seen as individuals: learning names, remembering previous conversations, incorporating their interests into examples. Run a survey to find out what degrees your students major in, review course notes from the other classes they are taking, arrive to class a few minutes early and leave a few minutes late to allow for casual conversations to take place. Building rapport is not about becoming friends, but you do want to be an ally on your students' learning journey. Relationships do not replace good assessment design or clear institutional policies, but they do make dishonesty feel like a betrayal of a relationship rather than merely a violation of a rule.

Final thoughts

We cannot remove every reason a student might cheat, but we can shape the environment in which that decision is made: we can make honest success feel achievable, make dishonest opportunities harder to exploit and create a course environment in which cheating is harder to rationalize. My students are adults and ultimately it is their right to fail. At the same time, I want them to "practice who you want to be" (thanks to Michelle Obama for inspiration) and explore the opportunities to demonstrate the qualities that matter in the long run. My responsibility is not to control my students' choices, but to create a course in which the honest choice is possible, meaningful and worth making.

****

F

1. K. Garaschuk, Why do students cheat – an economic approach , CMS Notes, 57 (5), 2025, https://notes.math.ca/en/article/why-do-students-cheat-an-economic-approach/
2. K. Garaschuk, Group exams: the good, the bad and the students' comments, CMS Notes, 49(2), 2017, p.~10–12, https://notes.math.ca/archives/Notesv49n1.pdf
3. K. Garaschuk, E. Cytrynbaum, Feasibility and effectiveness of group exams in mathematics courses, Problems, Resources, and Issues in Mathematics Undergraduate Studies, 2019, Issue 10, p. 1061-1079.
4. K. Garaschuk, Learning benefits of collaborative exams, Journal for Research and Practice in College Teaching, 2022, 7(1), p. 42–55

Mathematics Assessment Season

Education Notes

Egan J Chernoff (University of Saskatchewan)

It seems like there's a "season" for everything these days. Pollen has a season. Canada's federal budget has a season. Taxes, ticks and wildfires have a season. Heck, pumpkin spice lattes have a season. Some seasons even have official (and unofficial) start and end dates. According to Starbucks, Pumpkin Spice Latte Season has an official start date of August 25th this year. Seasons also vary. A winter can be harsher than other winters, for example, and a wildfire season can be more devastating than others (see, British Columbia, 2023).

With the horse already out of the barn when it comes to seasons, which it is, I ask for your indulgence as I propose a new one here in Canada: Mathematics Assessment Season. With no official start or end date, the beginning of Math Assessment Season (which coincides with Back-to-School Season) runs from late August through to early September and often continues through September and then ends in October or, in rarer occasions, in November. As mentioned, seasons vary, and how long, exactly, Math Assessment Season lasts each year relies on a number of factors.

Mathematics Assessment Season, as in years past, can be over in the blink of an eye. In and out along with Back-to-School Season. Not this year, however. No, this year, this year in particular, I think we'd all better hunker down for, what I predict, will be a long Mathematics Assessment Season. Cards on the table, I have not read The Old Farmer's Almanac for this year, and I do not know Wiarton Willie and, even if I did, the translator apps on my iPhone (e.g., Apple, Google and DeepL Translate) don't have "Groundhog to English" as an option. I have, though, kept my ear to the ground for many, many years.

Like every year, Back-to-School Season is an excuse for traditional media, that is, newspapers (e.g., The Globe and Mail or The Toronto Star), radio (e.g., The Current or Cross Country Checkup) and television (e.g., The National), to run a bunch of stories which present a narrative that, essentially, Canadian kids are not performing all that well on mathematics assessments. In Ontario, for example, traditional media will reference EQAO (Education Quality and Accountability Office) testing and explain that student achievement in mathematics isn't what it should be for a country as great as Canada. Similarly, over in Alberta, media will reference the PATs (Provincial Achievement Tests) written by students in grade nine and, again, the results will be presented in a manner where we could and should be doing better in a subject as important as mathematics. I should point out that this negative narrative is par for the course during Mathematics Assessment Season. After all, there's an old media adage, "If it bleeds, it leads", and Canadians not doing well in mathematics is a news story that, year after year, has legs. What happens next is typical, as well.

My favourite part of Mathematics Assessment Season is the subsequent feigning of interest by the Canadian public and, especially, the hyperbole. Sure, there's the inevitable water cooler conversations, which typically focus on a tired debate over the different ways that mathematics is getting taught in schools, which is always couched relative to how it was taught "back in the day". Once the debate over teaching gets tired then the story starts to die then the inevitable hyperbole keeps the story going.

One of my favourites was circa 2012 (which was a particularly robust Mathematics Assessment Season) when John Manley, then CEO/President of the Canadian Council of Chief Executives (and former Deputy Prime Minister) declared a "national emergency". The impetus for his declaration, the math results from PISA 2012. Every three years the Organization for Economic Co-operation and Development, better known as the OECD, conducts the Program for International Student Assessment, better known as PISA, where 15 year old students from over 60 countries take a standardized exam that focuses, in part, on mathematics. In other words, a nearly global mathematics assessment. Canada had, again, performed above average, but Canadian math scores on PISA were continuing to decline. Me, I took it upon myself to learn that Canada, in fact, had a National Emergency Response System at the time and, rightfully so, at least based on my reading of the document, the response system was not actually employed despite a national emergency being declared.

Sure, I may be being a tad hyperbolic myself, but my understanding is that what's good for the goose is good for the gander. Take, by way of a second example, an editorial from The Globe and Mail, which noted, "And when a country's ranking collapses, it is rightly treated as a national disaster." There was me, again, this time checking out our National Disaster Mitigation Strategy. Digging through the document, I could not find the appropriate support for implementing the National Disaster Mitigation Strategy because Canadians students performed above average, but were, overall, declining in their performance on a global mathematics assessment. Mathematics Assessment Season circa PISA 2012 was quite hyperbolic. National disaster, national emergency, but surely things couldn't get more hyperbolic!?

"Hit 'em where it hurts", as the saying goes. Take Trevor Howell, working for the Calgary Herald, who reported:"'How can we be satisfied with 13th place in math when we're not satisfied with second place in hockey' [John] Manley told a crowd of teachers, industry professionals, school board members and provincial politicians in Calgary on Wednesday". Manley's reference to "13th place in math" was, of course, referring to where Canada ranked in the 2012 PISA results and "second place in hockey" was, of course referring to Canada's dissatisfaction with winning anything but Gold in Olympic hockey, which had just happened in 2010 in Vancouver. For the record, I agree, Canada is good at hockey.

PISA takes place every three years, which means that PISA 2012 results were followed by results from PISA 2015, 2018, and 2022 (COVID being thrown into the mix, yes). In the interest of full disclosure, I closely follow PISA results and, especially, the resultant PISA Hullabaloo, which I consider a key part of my job. I contend, only to the best of my knowledge, that Mathematics Assessment Season circa 2015, 2018 and 2022 were calmer and quieter seasons compared to 2012. Sure, the debate over the best way to teach mathematics was present in print, radio and television media. Sure, people feigned interest and outrage. Then, however, the seasons were just over. Unlike 2012, I didn't hear about a rally being held at a provincial legislature, I didn't see newspapers running 44-part series on "The Great Canadian Math Debate", I didn't see petition after petition getting signature after signature, and I didn't see provinces scrambling and messily changing mathematics curricula. I didn't see a national story that had legs for years and would pop up in the most unlikely of places (e.g., Costco Connection: A Lifestyle Magazine for Costco Members). As alluded to earlier, the results from PISA 2025 have the potential for a particularly blustery Mathematics Assessment Season akin to 2012.

There are some specific factors that, I think, support my contention for a devastating Mathematics Assessment Season this year. All the issues with our "neighbours" to the south ("51st state", Lake Ontario America, etc.) will lead to cranky comparisons with mostly one other country. The looming question as to whether Alberta should remain a province of Canada will also lead to quarrelsome comparisons within our country as currently comprised. Jacob Tsimerman, the second Canadian and first scholar based at a Canadian institution, to win the Fields Medal will, somehow, support some weird arguments about how, as a country, "See, we can do anything if we just put our minds to it". The largely ignored results from the "other" global math assessment, the Trends in International Mathematics and Science Study (TIMSS) 2023 will start to see the light of day, albeit many years later. Sprinkle social media into the mix, add the notion that nearly everyone has a podcast, and all the components for a long-drawn out Mathematics Assessment Season are there for this year.

Expressing all of this to a colleague the other day, they asked me, politely (of course), how I was going make it through Mathematics Assessment Season this year. I thought about it for a little bit, not too long, and let them know that the recent FIFA World Cup is where I would find my solace this season. Sure, we may not be satisfied with second place in hockey, as John Manley rightfully noted all those years ago. At the recent Olympics, though, we did come in second place. Three times: Para, Women's and Men's Ice Hockey! Were we satisfied, no, which got me to thinking that perhaps hockey is not the proper comparison for Canadians when it comes to Mathematics Assessment Season in PISA years and where we rank relative to the world.

This last summer, I thoroughly enjoyed following the FIFA World Cup 2026. Canada, along with Mexico and United States, co-hosted for the first time. Amazing! Canada, for only the third time ever, played in the World Cup. Also, amazing! As a country, we earned our first group stage point (drawing against Bosnia and Herzegovina) and World Cup match win (over Qatar). Are you kidding me, amazing!? Canada even made it out of Group Stage play, won over South Africa in the elimination round of 32, but then, unfortunately, lost to Morocco in the round of 16. What a run for Canada! I also enjoyed how happy and proud Canadians were for how well Canada performed on the world stage.

At the FIFA World Cup 2026, Canada, officially, finished in 14th place. People were happy with the result. People were proud of the result. Nobody really thought we were going to win the World Cup. After all, Canadians are a humble bunch. Please keep the recent World Cup in mind, especially when the 2025 PISA results get released and things start to get out of hand, which they might this year. Mathematics Assessment Season is Coming…

The Sky Took Us

Book Reviews

KaNilima Nigam(Simon Fraser University)

Book Reviews bring interesting mathematical sciences and education publications drawn from across the entire spectrum of mathematics to the attention of the CMS readership. Comments, suggestions, and submissions are welcome.

Andrew Hare (Saint Mary's University) (notes-reviews@cms.math.ca)

Book Review



by Dr. Nilima Nigam (Simon Fraser University)

.

Here's an opening to a novel that is like catnip to a mathematician: "The logic held." Within the span of the first paragraph, Anthony Bonato evokes in us the familiar shaky, exhilarated, dare-I-believe-it feeling that we get when we've proved something challenging. It's a magical, rewarding sensation that provides fodder for our ambitions and fuel for the long, difficult, frustrating journey. Now imagine you're a sixteen-year-old-girl, live in Toronto, and have just proved the Riemann Hypothesis. Your mom adores you, but also keeps you tethered to reality 'I can't remember what you proved last week, baby'. Also, your guitar-playing cooler older sister annoyingly reminds you that you're not the center of the universe. Everything is just about to get strange, and scary, and your biggest challenge is yet to come. A giant dark floating orb appears over Sankofa Square, flashing patterns – and then it stops. Your mom disappears. In fact, many such orbs levitate, menacingly, above major cities; millions are taken. You're recruited into an international task force to decode the message in the flashing patterns on these orbs, your goal nothing short of saving humanity. Proving the Riemann Hypothesis is the second most important thing you'll do.

Many of us have encountered Bonato's engaging mathematical exposition, and when I started this novel I was prepared for excellent writing. What I did not anticipate – but loved! – was the excitement of the plot: Aliens, the Collatz conjecture, Erd¨os-Ramsey theory, a team of brave people tasked with saving the world and a certain hilarious coffee mug. As the plot progresses, our heroine grapples with more than just an apocalyptic end to humanity. It's a wildly stimulating high-stakes mathematical romp (6 words that rarely appear in sequence). It's also a meditation on beauty, identity and humanity, all through the eyes of an inspiring young person. She reminds us that heroes come in all guises, and that our connection to mathematics is both very human and universal. This gem of a book grips the reader from the very first page. A science fiction coming-of-age novel, a treasure-chest of mathematical ideas and puzzles, this is above all a moving story about love, connection and communication. This summer the news featured daily reports of amazing LLM-related achievements in mathematics. I confess none of them filled me with as much awe and joy this summer as the mathematical adventures of young Kris. 'The Sky Took Us' comes highly recommended, to be enjoyed with a side of dark chocolate and coffee in a certain white-with-red-lettering mug.

Exploring EDI: Definitions, Examples and Conjectures

MOSAIC

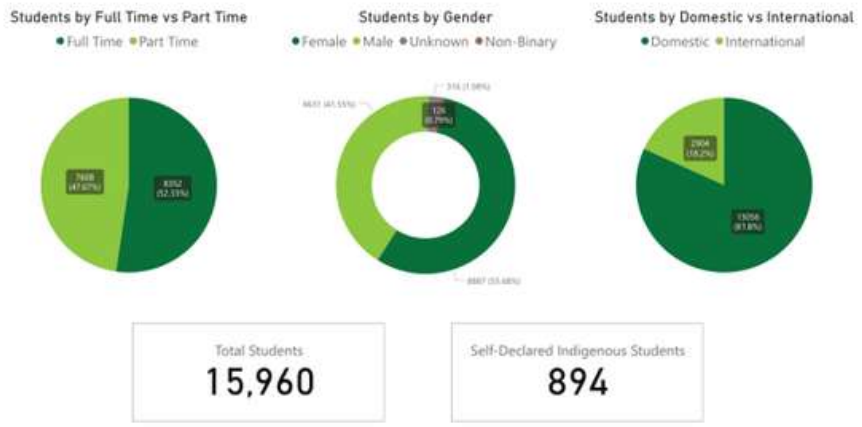
Kseniya Garaschuk (University of the Fraser Valley)

Editor-in-Chief, CRUX & Chair of Equity, Diversity and Inclusiveness Committee

I am sure the majority of the readers can tell me what the E, the D and the I stand for in EDI, but what are the actual definitions of those words? Do they overlap? Do they cover everything we want covered? Let's start with some definitions and exploratory work.

As mathematicians do, I would like to start with definitions and discuss the terms in the acronym. I'd like to note that while I read and listen to many books/blogs/podcasts on all things EDI, I have been particularly impressed with Michael Bach's book "Birds of all Feathers" for its clear and engaging way of laying out the terms and supporting them with implementation notes. Taking a lesson from this book, the first term I'd like to introduce is neither of the three in the acronym EDI. It is representation.

Representation is what we can count. There are many things we can count, ranging from one-dimensional to quite complex, but it is purely quantitative. Every institution likely has a graphic similar to the one presented below from my previous home institution, University of the Fraser Valley:



Such data can inform many decisions taken by both administration and academic faculty. For example, based on the above, one can recognize that the average student demographic includes a large proportion of part-time students that likely have some combination of part-time jobs, caretaking responsibilities and more, shifting their preferences for class format (in-person versus online) and scheduling (day classes versus night classes). Noting the proportion of international students, one can dig further into this data to find that the majority come from India; this important observation might drive decisions around scheduling examinations and other events around non-Western cultural and religious holidays. The representation shows us the snapshot of the demographic at a point in time. But it neither captures all of the complexities of the data, nor does it in itself drive action or change. It also doesn't capture the very real and tangible experiences of the humans it is counting.

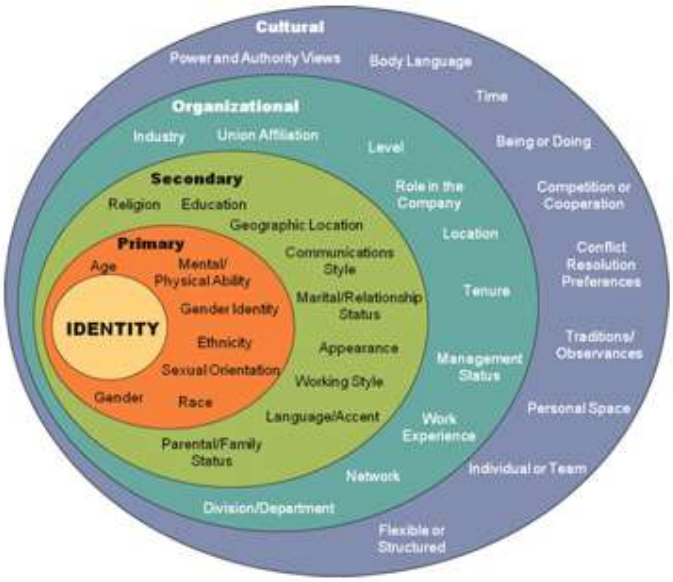
Next up, I offer you Diversity Bingo. It is what it sounds like: imagine you are in a group of 20 or more people who you don't know and you are handed out a Bingo card as below. You're to go and chat with people and you're allowed to only cross one square per person for as many squares on the card as you can in 5 minutes. This is clearly not enough time to get to know anyone holistically, so in order to cross off the squares, you will have to ask blunt questions of strangers.

Diversity Bingo

Person over 35 years of age.	Person who has changed career paths.	Person who uses they/them pronouns.	Person who speaks more than two languages.
Person who is Indigenous.	Person who is a first generation Canadian.	Person who is left-handed.	Person who is the oldest or only child.
Person who is a caregiver for a family member.	Person who has lived in another country for more than 6 months.	Person of Middle Eastern heritage.	Person who has received Employment Insurance.
Person who identifies as neurodivergent.	Person who grew up in a rural or remote area.	Person who has different religious observances from you.	Person whose daily commute is 40 minutes or more.

Which questions are easy to ask and which ones are hard? Which aspects of diversity do you think are visible? Which questions are you more likely to ask someone after a 5-second interaction based on the person's accent (or lack thereof) or their skin colour or clothing style? This simple exercise highlights the differences between what is visible, what is countable, what is assumed and finally what is meaningful. How quickly and how often do we judge our students based on their appearances, accents or handwriting?

A few details about diversity follow. They are included to ensure we all share a clear understanding of the terms, but you may skip this paragraph if you're comfortable with the terminology. Diversity has many aspects. You can find various examples of a "diversity wheel", which is helpful in understanding that there are many dimensions of diversity, here is one such example:



Here, I will give a simpler model by only discussing two broad layers of the wheel, let's call them foundational and contextual. The foundational layer encompasses core human elements that are internal to one's identity: age, ethnicity, sexual orientation, gender, gender identity and others. The contextual layer consists of external factors, such as religion, education, geographic location, parental status, traditions and observances, political and economic systems and so on. A person's foundational characteristics influence how they navigate different contexts and how they are perceived by others within those different contexts, while the contextual factors shape which aspects of the identity are valued, challenged or even visible (or allowed to be visible) in a given environment. Diversity is complex: people are not just representatives of a finite set of categories, but individuals whose lived experiences are shaped by the overlap of the many dimensions they live(d) in. One important thing to note here is that any given individual can only control some of their diversity characteristics for themselves: the further away we move from the foundational layer, the less agency one has since the given aspects are shaped by circumstance, environment and social structures as opposed to personal agency or choice.

Representation and diversity, though often used interchangeably, are not the same. The first is a quantitative measure of who is present. The second is more of a texture, a sense of how varied those presences are.

What we can now conclude is that in a group of 2 or more people, we have diversity. And hence we have to be more precise when we talk about targeting diversity and provide actual axes along which diversity (and the progress towards it) will be tracked. For example, starting in summer 2024 CMS introduced diversity considerations into their conference session proposals and we are still working on the rubric to help organizers assess the diversity. To be clear, I'm not contradicting myself – a group of white, able-bodied, straight, tenured mathematicians from Waterloo is still a diverse group by some metric mentioned above. This is why in the guidelines developed by the EDI committee for CMS sessions, we ask organizers to consider various categories, such as:

- career stages,
- educational/racial/ethnic/linguistic backgrounds,
- belonging to equity-seeking and historically underrepresented groups (including women, minorities, francophones, members of the LGBTQ2S+ community, persons with disabilities, etc),
- organizational affiliations,
- types of home institutions (small teaching schools vs large research focused),
- geographic locations.

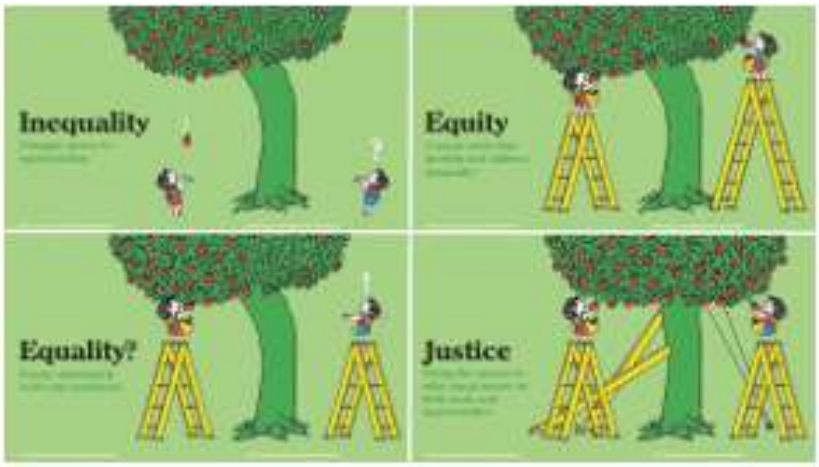
While it is of course not possible to have diversity along all the axes in a single session, I think we can agree that my edge example from above (a group of white, able-bodied, straight, tenured mathematicians from Waterloo) is certainly lacking.

We established that diversity is a fact. Inclusion, however, is a choice. And this is where reality comes in. You can hire a candidate from a historically underrepresented group (in math department, this is likely some version of female/person of colour/Indigenous/disabled) and then do nothing else – except perhaps congratulate yourself on the "diverse" hire and call it progress. What issues can possibly arise? Well, many. Here is a particularly poignant example that emphasizes that we aren't so far removed from the era of men-only education:

https://numberlandadventures.blogspot.com/2017/09/are-urinals-in-womens-rooms-sign-of.html which talks about the presence of urinals in women's washrooms in math departments of many prestigious old universities across North America, an ironic sign of slow and inconsistent progress toward gender equity. While I am here, I highly recommend Alice Silverberg's entire blog, not just the single piece linked above.

Diversity without inclusion is not progress. And inclusion is hard work – you have to explore barriers that are invisible to you but are real for others. This ranges from physical barriers to cultural to anything in between. I am an able-bodied, white woman. I am 5 '4", an average height for a Canadian woman, but apparently too short for an average academic because I have been unable to reach the top 20-30% of the blackboards in the majority of the classrooms I have taught in. As a result, I have to plan out my board usage very carefully as I literally have less space to work with than most. I thought I would leave this issue in the past thanks to technology and skeleton slides – only to discover that the podium height on which I rest my tablet is a whole other issue. Details aside, let's be honest – how many of you have thought that something as mundane as furniture height or classroom layout can quietly determine who is comfortable teaching there and who is not? I will give another, even more personal example. I suffer from an episodic condition that causes my blood pressure and heart rate to plummet, rendering me physically unable to move for a couple of hours. Luckily, this only happens 3-4 times a year and I get a strong wave of vertigo first thing in the morning as a warning sign. Unluckily, my in-person teaching responsibilities and a strong sense of professional ethics leave me facing a moral dilemma every time. Do I cancel class at the last minute, inconveniencing students, or do I push through, risking a collapse mid-lecture? If I cancel the class, how will this affect my student evaluations? How will asking for a substitution last minute reflect on my reliability? How will all of this affect my career? I know that many people with chronic or episodic conditions, visible or invisible, navigate similar choices every day. Accessible building entries, moveable boards, universal washroom facilities, flexible teaching schedules and formats, a tenure clock that accounts for life, funding structures that don't penalize career interruptions, recruitment and promotion practices that do not exclude those with non-traditional career paths. inclusion is not about accommodating one person's needs – it is about designing systems that work for many.

The last letter – the E. I will let the picture do the talking for me here:



Back to data for the last concept I want to mention: intersectionality. According to Statistics Canada and 2022 Census data, men earn higher salaries than women across all categories – age, geographic location, level of education, immigration status, etc. Overall average income of men in 2022 constant dollars was $17,600 higher than that of women. So men make more than women, we have certainly known that for years. However, women are not one uniform group and the data shows big discrepancies when intersectionality in education, citizenship and basically any two categories is applied. For example, Canadian-born women out-earn women who have immigrated to Canada, but that gap is much smaller for individuals without a university degree. Only recently have we as a society started analysing multi-faceted data across various characteristics to better understand compound barriers and necessary mitigations. Various practical considerations of intersectionality can be found in the report from the Canadian Research Institute for the Advancement of Women (where the table below is taken from).

Median Earnings/year

	Canadian born population (men)	Canadian-born population (women)	Immigrant population (men)	Immigrant population (women)	Recent Immigrant population (men)	Recent Immigrant population (women)
With a University Degree	$ 62,566	$ 44,545	$ 42,998	$ 30,633	$ 30,332	$ 18,969
Without a University Degree	$ 40,235	$ 25,590	$ 33,814	$ 22,382	$ 24,470	$ 14,233

Source: Statistics Canada, 2006 Census data (for the year 2005)[9]

Now that we understand the terms, let's ask the big question – why EDI? Why should universities (or another organization) strive to attract and retain diverse talent? Why should we expand time and effort to adjust our existing approaches to hiring? Why challenge practices that have "worked" for decades? Why invest in structures that might slow down short-term efficiency? Why make ourselves uncomfortable by questioning habits we didn't even know we had? Why EDI

Because it's the right thing to do.

This is not a good answer simply because it is not supported by a good solid argument. There isn't a single "right thing" that everyone agrees on; people's values and priorities differ, sometimes wildly; everyone has their own moral compass and most of us will bend or adjust it to convenience or circumstance (let's face it, we have all at some point in life considered a particular speed limit as optional). Ethics are subjective by nature – everyone thinks they're on the right side of history, even tyrants. Morality alone will not move institutions, budgets or egos.

EDI must ultimately be centered in shared human values and the creation of an inclusive community. Our foundation is a human-centered one. But the reality is that institutional decisions are often driven by incentives, finances, competition and resource considerations rather than shared moral frameworks — which are not consistent across individuals. What tools do we have to help motivate action in contexts where moral arguments, while valid, have historically been insufficient to produce change?

So why EDI?

Because it's good for business – whatever your business is. According to Statistics Canada and Census 2022:

- women account for 50.9% of Canada's total population aged 15 and older;
- Indigenous people represent 5.0% of the total Canadian population and Indigenous population is growing at a rate almost double that of the non-Indigenous population;
- the proportion of visible minorities in Canada is 26.5%;
- in 2022, 27% of Canadians aged 15 and over reported having at least one disability.

Excluding any of the above groups (intentionally or not) from opportunities is quite literally limiting yourself away from a significant proportion of the population and hence available talent. When half the country doesn't even see your department as a plausible destination, then you cannot claim that you are attracting the best and the brightest. If the pool you draw from remains narrow by design, then the outcomes will remain narrow as well, by design. If you're serious about attracting the best people (student and faculty alike), EDI is a competitive necessity. To be clear – you need all of the E, the D and the I, because it certainly isn't helping your case if the retention of the diverse talent is low, while the word on the street about the dysfunctional culture is spreading.

As a first side note, I do have to mention one ever-present issue. The "pipeline" problem does not start at the age when our students enter the workforce or even the university system. It is widespread through generations and across the whole society. I'm a woman and gendered statistics are easily available, so let me focus on those for a minute to illustrate the point. According to various studies, girls are more likely than boys to self-select out of advanced STEM courses in secondary school and beyond. We of course see the results of this on the other end. For example, according to the University of Waterloo CS studies website, thd percentage of women awarded BSc, MSc or PhD in CS studies hovers around 25%. This is supported by the more general data from Statistics Canada: while women constitute just over 60% of recent Bachelor degree holders, they represent only 29.6% of those graduating with degrees in the field of "Mathematics, computer and information sciences" with Quebec and BC showing the highest provincial levels. This of course implies that eventual workforce availability of women candidates is lower, propagating the problem into all STEM and STEM-adjacent industries, which tend to have higher wages than non-STEM fields (see here).

Most people are familiar with the program pyramid: the four layers consist of the number of students taking courses at the corresponding years/levels. The mathematical "base" is quite heavy because math departments are large service departments, with students in many, if not most, programs having to complete a math requirement. The second layer is lighter, restricted to students in math and various sciences. Third and fourth layers consist largely of math students (majors and minors) with a few adjacent disciplines. While the shape of the pyramid will inevitably be narrower at the top, we would like to strive for a more gentle slope. And let me remind you that over 60% of Bachelor graduates are female, which means we have a captive audience that chooses to explicitly not participate in our programs. You want to increase your numbers – tap into the untapped. You don't even have to go far: for example, according to the same stats, women represent over 60% of the graduates in "Physical and life sciences and technologies" where additional mathematical background could be of interest if they want to enter the fields of bioinformatics, biostatistics, medical imaging and more. The students are already here, and in fact they are already succeeding in adjacent disciplines where mathematical and computational skills are increasingly valuable. The challenge is not an absence of talent or absence of interest, but a failure of inclusion. Are our introductory courses and advising structures welcoming to students with diverse goals? Do our curricula highlight connections to applications and interdisciplinary pathways that resonate with students in adjacent fields? Do we have flexible entry points into the minor or major programs? Can we speak coherently to career-relevant skills and applications?

A second side note is in the failure of connection. What we also face is a misalignment between what we teach, how we frame our fields and how students perceive their place within them. This, however, is a big topic that I will need motivation to write about – drop me a line if you'd like to hear my thoughts.

In conclusion to my slightly all over the place piece above: EDI is not about quotas and there is no metric that will allow you to check the box on successfully diversifying your program. EDI is a method and a way of thinking. It is a way of questioning our systems with the same curiosity we bring to our research.

New Worries of an Old-Fashioned Colleague

Contributed Article

Dr. Javad Mashreghi (Université Laval)

There are moments in the life of a mathematician when one realizes that the rules of the game may have changed without anyone announcing it. For me, one such moment came in early August at IWOTA 2026, held at Laval University. One of the dominant topics of the conference was the solution of the two-decade-old Crouzeix conjecture. Many prominent mathematicians had tried to settle this conjecture over the years. Their efforts had not been successful, but they had produced several beautiful new results that were interesting in their own right. Indeed, I once said that I hoped the conjecture would not be settled too soon, so that we could continue to witness interesting discoveries in matrix analysis and operator theory. And then, quite suddenly, using AI, the conjecture was settled by a colleague who was not even a member of the analysis community at large. A second proof was presented at IWOTA at the same time. My point here is not to discuss the priority, validity, or relative merits of these proofs. What caught my attention was something more fundamental: the possibility of obtaining a major mathematical breakthrough with the assistance of AI.

We are often told that AI has absorbed the entirety of the mathematical literature (books, papers, and publications accumulated in the major libraries around the world) and that its virtually unlimited memory allows it to retain this vast body of knowledge. Its computational power far exceeds that of even the greatest mathematical minds in history. It has access to enormous amounts of energy and knows nothing of fatigue, aging, illness, or anxiety. In short, AI is presented to us as something approaching the superhuman. And yet, we can only look with awe at what has unfolded in recent weeks.

Once such possibilities became visible, students and experts naturally began trying their chances on other longstanding problems. There are examples where, within a few hours, successful proofs have been obtained. These are remarkable achievements, and I do not intend to diminish them. Nor is this article an attempt to praise or criticize those who have used AI successfully. My purpose is quite different. I want to bring to the attention of our academic leadership and administration something that is possibly much less visible than the excitement surrounding these breakthroughs: the high level of worry and anxiety that they have created among mathematicians.

Mathematics, understood as a science built by human beings, is an invisible fabric extending from the most influential and creative researchers at the world's most prestigious research centers, through universities, colleges, and high schools, all the way down to those who teach young children to count, sometimes beginning with their fingers in kindergarten. Along this long continuum, every single part matters. We cannot simply leap from one point to another without losing something essential along the way. The growing presence of AI in our lives therefore naturally brings with it new ambiguities, as well as new sources of concern.

At first, a confession:

My own use of AI has so far been extremely modest. I have mainly used it for relatively simple tasks, such as polishing English or French texts, including this article. I have also recently worked with a collaborator who makes use of AI to check and verify results in a research paper. Beyond such uses, however, I remain largely unfamiliar with the capabilities of AI and, in particular, with how it might be used effectively and constructively in mathematical research or in making scientific discoveries. In fact, I use AI at what I would consider the lowest possible level, and I do not claim any real expertise in its use. Perhaps that is precisely why I am writing this note. I have observed various developments, spoken with colleagues and friends, and listened to many discussions, and all of these experiences have considerably increased my concerns. I therefore write simply as a non-expert, and perhaps somewhat old-fashioned mathematician, trying to make sense of a reality that is entering our professional and intellectual lives at an extraordinary speed. Thus, these reflections bring together optimism, realism, and a measure of apprehension about what lies ahead.

What Do We Mean by a 'Researcher' Now?

Let us begin with the three major criteria that grant agencies apply in evaluating our grant applications. The first is the quality of the researcher. Quite frankly, I think we now need to ask what we mean by a "researcher" in this new era. We may consider two extreme scenarios. On the one hand, a prominent colleague works on difficult problems, possibly from long before the AI era, and then, through back-and-forth assistance from AI, finds the right paths and settles the problem. On the other hand, another colleague puts all the burden of an open problem, including even the writing of the article, on the shoulders of AI and comes up with an article to claim authority on it. The spectrum of AI use is very wide, and the community is spread between the two extremes mentioned above.

It is likely that we will eventually reach an equilibrium point where colleagues properly exploit AI in their investigations. However, it is not clear when we will reach that point, and there is currently no means for institutions and grant agencies to categorize applicants and distinguish between their different levels and forms of use of the available technology. Hence, the question of assessing the quality of researchers remains wide open.

The question becomes even more complicated when some colleagues openly say that they have written a high number of research articles in the past year using AI, and that these articles have subsequently appeared in reputable peer-reviewed journals. At the same time, there remain traditional mathematicians who believe deeply in the intrinsic nature of mathematics, in the importance of struggling with a problem, developing intuition, making mistakes, finding the right question, and eventually discovering a proof. Their publication records do not remotely match those of colleagues who make extensive use of AI. The gap between these two categories seems to be growing rapidly. How can we fairly evaluate the quality of researchers in such an environment? I do not have an answer, but I believe we need to begin asking the question.

And What About the 'Proposal'?

The same phenomenon applies to the quality of a research proposal. As far as I understand, the agency does not currently have the means to determine whether a proposal was written with the assistance of AI, or even whether it was subsequently evaluated with the assistance of AI by external reviewers. The system essentially has to trust the candidates and the reviewers. This adds another degree of complexity to an already difficult process. More importantly, it creates a fear that some researchers may be disadvantaged simply because they use AI less extensively, or choose not to use it at all.

If one researcher spends weeks thinking about how to formulate a problem, explain its significance, and develop a research plan, while another can ask an AI system to generate and refine a proposal in a fraction of the time, are we still measuring the same thing? And if AI becomes increasingly involved not only in writing proposals, but also in proposing research ideas, suggesting approaches and methodologies, and reviewing manuscripts, how should we distinguish and assess such proposals? These are not easy questions. But avoiding them will not make them disappear.

The Doctoral Student: My Greatest Worry

There is one issue that worries me more than all the others: the training of doctoral students. In the traditional approach, we give modest problems to fresh doctoral students and gradually guide them toward more complicated questions. We teach them techniques, but we also teach them how to think. We expect that, after four years of study, they will have developed enough mathematical maturity to approach problems that were initially beyond their reach. Along the way, we hope for a glorious outcome: a new theorem, a new method, perhaps even a new direction. But what happens when many of the modest, down-to-earth problems that we would traditionally give to beginning students can potentially be settled in half a day? How should we train doctoral students in such an environment?

Suppose we engage a student in a serious problem. The student spends months learning the background, trying approaches, failing, starting again, and slowly developing an understanding of the problem. Then, with a high probability, another AI-assisted group may answer the same question. What do I tell my student?

I feel responsible for the lives and careers of my students. I cannot accept the possibility of working with them for a couple of years and then being forced to say, "I am sorry; someone else has solved the problem." This is not merely a question of efficiency or academic competition. We are talking about the future of a young human being. And we are responsible for it. For me, this is the most worrying aspect of AI's invasion of our academic life.

A Possible Future Doctoral Program

The nature of doctoral training is changing rapidly, and we need to adapt to these changes. The training of doctoral students will likely look different in the future and will place greater emphasis on different goals. One possible direction (certainly not the only one) would be to have doctoral students take more courses and receive a broader education in mathematics. This could also lead to a new model of doctoral thesis, one in which producing a "new product" in the traditional sense is no longer the sole or even primary standard.

It is also conceivable that the number of students pursuing research careers will decrease. In that context, doctoral programs could place greater emphasis on broad mathematical education, preparing students to become better teachers and mentors. This does not mean transforming doctoral programs into education programs. Rather, students could take sevarl inspiring mathematics courses that they can carry with them into their future positions. The doctoral student of the future may need to become a wise curator of mathematics, rather than necessarily a researcher in the traditional sense. Many doctoral graduates ultimately become mathematics professors whose primary responsibilities are teaching and mentoring, rather than research. A doctoral program that recognizes this reality could provide students with a broader, deeper, and more versatile mathematical education, while still preserving opportunities for those who wish to pursue research.

Will We Still Write Books?

Another, perhaps less important, issue concerns the writing of books. Being an author is a difficult task. It requires an enormous amount of energy, time, patience, and sacrifice. Moreover, after completing a book project, the rather meagre financial benefit that comes with its publication is yet another factor discouraging mathematicians from writing another one. Now add to this the fact that, for almost any topic, AI can potentially produce a well-organized document based on the available literature. Does it still make sense to write a new book? Perhaps the form of future mathematical publications will be totally different.
In fact, if you visit the office of a prominent professor and compare it with that of a recently hired colleague, you may already observe a major difference. The new professor may have only a few books in the office, together with a huge library of PDFs on a laptop, while the old-fashioned colleague's office is stuffed with all kinds of printed books and journals. This may sound like a trivial observation. But it is also symbolic. The way we store, access, read, and produce mathematical knowledge is already changing. And I suspect that we have seen only the beginning. More changes are ahead!

Perhaps we are moving toward a new kind of research institution, one with no traditional library and perhaps not even a dedicated office for each researcher. There may be little need to store large quantities of PDF files locally, since research materials could be accessed digitally whenever and wherever they are needed. Researchers and students would move back and forth between their residences and shared meeting rooms, while much of their intellectual interaction would take place through computer-mediated dialogue. The physical spaces might consist largely of meeting rooms without chalkboards or blackboards, complemented by access to sophisticated and highly specialized computing facilities. In such an institution, the traditional infrastructure of research would be replaced, to a large extent, by digital connectivity, shared computational resources, and some spaces for meetings and collaboration.

The Burden of Editorial Duties

The sheer volume of mathematics that AI-assisted systems may produce is difficult to comprehend. The number of submissions to research journals is already becoming a heavy burden for editorial teams. More fundamentally, if the pace of mathematical production increases dramatically, researchers may no longer have the capacity to absorb, evaluate, and make sense of everything that is being generated. We risk being overwhelmed not by a lack of mathematics, but by an abundance of it. Therefore, thicker volumes of research journals are not necessarily a sign of progress.

Mathematics requires time to digest. Understanding, connecting, simplifying, and placing new ideas within the broader mathematical landscape are essential parts of mathematical progress. In an AI-assisted future, one of the most important roles of mathematicians may therefore be not simply to produce more mathematics, but to curate, interpret, and digest the mathematics being produced.

Can AI Lead Us?

We have all experienced the familiar fact that every problem we solve immediately gives rise to a multitude of new ones. The landscape of mathematical questions is not finite or static; it resembles a tree, or perhaps a hyperbolic manifold, continually branching and expanding toward infinity. Human thought has repeatedly opened entirely new regions of this landscape by introducing new concepts, new theories, and new ways of looking at familiar problems. This capacity to move beyond the questions we already know how to ask has been one of the driving forces behind the development of mathematics and, more broadly, of science and technology.

AI is extraordinarily powerful when it comes to navigating an existing landscape. It can combine vast amounts of knowledge, recognize patterns, and help us solve problems that may be far beyond the computational abilities of any individual mathematician. But this raises a more fundamental question: can AI lead us somewhere genuinely new? Can it formulate a new theory, introduce a fundamentally new concept, or open a mathematical landscape that we did not previously know existed? More explicitly, solving a problem is not, by itself, the ultimate goal of mathematical research. What may matter even more is understanding where a solution takes us: what new questions it reveals, what unexpected connections it uncovers, and what unexplored territories lie beyond it. Can AI navigate that road, not merely by finding its way through an existing landscape, but by discovering or creating landscapes that were previously invisible to us? I am not convinced that it can. Perhaps this is precisely where human mathematical creativity remains indispensable.

The ability of AI to solve difficult mathematical problems by combining and deploying existing techniques is not necessarily the same as its ability to generate genuinely new mathematical ideas or conceptual frameworks. Mathematics has often advanced through conceptual leaps that were not simply the result of solving increasingly difficult technical problems, but rather through the introduction of new viewpoints, structures, and connections between seemingly distant areas. The formulation of the Langlands program, for example, illustrates how a powerful conceptual framework can open entirely new directions and influence mathematics for decades.

A Brighter Future for Teaching

One of the most exciting consequences of the current transformation may be a renaissance of mathematical teaching. As AI takes over much of the routine, technical, and laborious work of learning mathematics, the role of the teacher will not diminish. In fact, it will become more important than ever. The mathematics teacher of the future will need to be a master of the classroom: someone who can make mathematics beautiful, intelligible, and alive. Teachers will need to reveal the deep connections between ideas and help students see the larger landscape and the new galaxy of mathematical discoveries emerging before them. AI may take care of much of the nitty-gritty, but it cannot replace the human act of guiding a student toward understanding, curiosity, and wonder.

The teacher's greatest role will be that of a mentor: someone who can lead students through the ideas of mathematics, illuminate the paths between them, and inspire them to see mathematics not as a collection of techniques, but as one of humanity's greatest intellectual achievements. This may be the beginning of a new golden age of mathematical teaching. The uninspiring mathematics teacher may no longer have a place in the classroom, not because teaching has become less important, but because it has become too important to be done without excellence.

Make Mathematics Beautiful Again! Make it understandable. Make it exciting. Make students want to discover what lies beyond the next theorem. For thousands of years, mathematics has endured because it possesses a beauty and power unlike any other human creation. If we embrace this new era wisely, mathematics can once again, and perhaps more brilliantly than ever, take its place as one of the shining sciences of all time.

Final Comments

I have seen a high degree of anxiety among doctoral students and among younger colleagues at the beginning of their careers. I have also sensed a great deal of worry among supervisors about the future of their students. There are many other issues that could be discussed concerning the effect of AI on our academic life. I am neither an AI expert nor someone who knows how to use it effectively. There is no doubt that there are many remarkable and positive features coming with this new technology, and we will eventually learn how to adapt to the new reality. But adaptation does not necessarily mean that the passage will be smooth.

Mathematics has always evolved with new technologies, from the printing press to computers and computer-assisted proofs. Perhaps AI will ultimately become another instrument in this long history. But there is a difference between acquiring a new instrument and confronting a tool that may fundamentally alter the way mathematical ideas are generated, tested, communicated, and even valued. My concern is that we may gradually arrive at a situation in which a relatively small number of experts learn to use AI thoughtfully and creatively, using it to advance mathematical knowledge, while a much larger number of people come to rely on it primarily as a means of producing mass scientific output. The danger, in my view, is not simply that AI could make certain tasks easier. It is that the ease of producing apparently sophisticated mathematical work might outpace the development of the mathematical understanding needed to create, assess, and question that work. We could then find ourselves with an increasing volume of papers and results, while the proportion of people who genuinely understand the mathematics behind them becomes smaller.

This possibility concerns me deeply. Mathematics is not merely the production of correct-looking arguments or polished texts; it is an intellectual activity that requires understanding, judgment, intuition, and, above all, the ability to recognize why an argument is meaningful and why a result matters. I would be equally concerned if we reached a point where even the ability to formulate a simple, ordinary letter in our own words became something we routinely delegated to AI.

Perhaps these fears will prove unfounded. Perhaps the future generation will look back at my worries with the same amusement with which we now look at mathematicians who once feared calculators or computers. I sincerely hope so. But for the moment, I remain worried. But there is also reason for optimism. Ultimately, mathematicians still get to decide what mathematics is interesting, what is worth pursuing, what is worth reading, and what deserves our attention. We are not obliged to consume everything that can be produced. In this respect, mathematics may be rather like art: if you do not find a work meaningful, you are under no obligation to hang it on your wall.

Acknowledgments

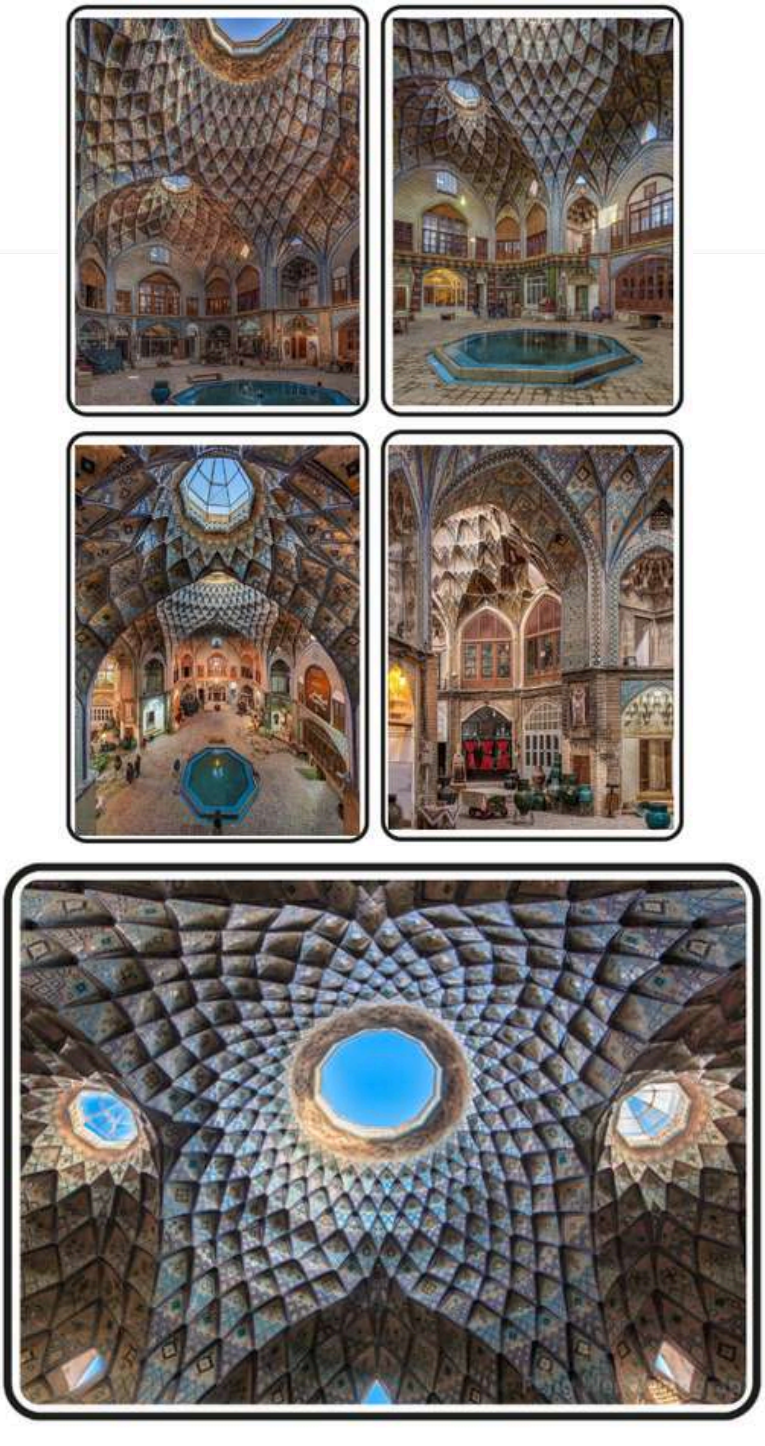
I would like to thank my friends and colleagues who took the time to read different versions of this note and generously shared their thoughts, insights, and suggestions. Their comments have helped me clarify and improve several aspects of the discussion. In particular, I am grateful to E. Fricain, F. Gourdeau, A. Girouard, N. Kamran, D. Kinzebulatov, N. Nigam, T. Ransford, and W. Ross for their thoughtful comments, stimulating discussions, and valuable perspectives. I greatly appreciate their generosity in engaging with these ideas and helping me reflect more carefully on the questions raised by this rapidly evolving subject.

Any remaining errors or shortcomings are, of course, entirely my own.

A pictorial story

Contributed Articles

Javad Mashreghi(Université Laval)
President, Canadian Mathematical Society



Timcheh Amin od-Dowleh, built in 1868, is one of several traditional plazas within the Grand Bazaar of Kashan, Iran. A timcheh is a specialized commercial space within a bazaar, typically smaller and more intimate than the main market streets, where merchants, craftsmen, and traders could conduct their business.

This building is distinguished by its remarkably high, multi-tiered dome, decorated with intricate stalactite vaulting and geometric brickwork. The symmetrical, two-story structure is organized around an open central courtyard, surrounded by small shops, offices, and commercial spaces. One of its most striking features is the large central skylight at the top of the dome. It allows natural light to penetrate deep into the building, illuminating the central hall and creating constantly changing patterns of light and shadow throughout the day. The combination of height, geometry, brickwork, and natural light gives the space a remarkable sense of scale and tranquility despite its original commercial purpose.

Timcheh was more than simply a collection of shops. It was part of a larger network of workshops, merchants, craftsmen, and traders that sustained the economic and social life of the city. In that sense, the building stands not only as an architectural monument, but also as a reminder of a time when commerce, craftsmanship, and community life were deeply intertwined.



Most traditional carpets feature a high degree of symmetry in their patterns. A particularly common approach is bilateral symmetry, in which the design is mirrored across both the vertical and horizontal axes. This symmetry provides a clear underlying structure that helps organize the many intricate elements of the pattern, from flowers and leaves to geometric motifs and decorative borders.



Because of the bilateral symmetry, the designer only needs to draw one quarter of the carpet pattern in full detail. The other three sections can then be created by reflecting this initial quarter across the vertical and horizontal axes. This simple mathematical principle greatly reduces the amount of work required while preserving the precise balance and harmony of the overall design.



The carpet designer's work required exceptional precision, patience, and artistic skill. Even a small error in the initial quarter of a pattern would be replicated through the reflections and could become visible across the entire carpet. Traditionally, professional carpet designers spent months developing a new pattern, carefully drawing and painting every detail by hand on gridded design paper, where the small squares provided a precise guide for positioning and reproducing the intricate motifs. Their work combined artistic creativity with remarkable attention to geometric structure, proportion, and symmetry.



The finished patterns then served as a guide for another group of skilled and hardworking artisans, who used them to weave the carpet according to the design. Depending on the type, size, and complexity of the carpet, the weaving process could take anywhere from several months to several years. A handmade carpet was never the work of a single person. Behind every finished carpet stood many skilled workers, each contributing a specialized part of the process, from designers and pattern makers to dyers, spinners, weavers, trimmers, washers, and finishers. The industry also supported a wide network of other businesses and trades involved in supplying raw materials, preparing and transporting them, selling the finished carpets, and maintaining the tools and equipment needed for their production. For generations, these interconnected occupations formed an important economic and social fabric, allowing entire communities to make their livelihoods through the creation and trade of handmade carpets.

After several centuries of accumulated experience, with knowledge and skills passed down from one generation to the next, this traditional society faced two new realities.



First, the emergence of powerful computers capable of designing and printing intricate carpet patterns in a matter of minutes.



Second, advanced industrial machines could weave carpets in just a few hours, tasks that had once required months or even years of painstaking work.



Returning to the initial photographs of Timcheh, the right-side office on the second floor once belonged to my grandfather, who was a carpet designer. When I was in primary school, I used to spend the hot summer months in this plaza. In today's language, it was somehow our summer camp, a place where I, along with other children, could enjoy all kinds of childhood activities while remaining under the watchful eye of the family elders.

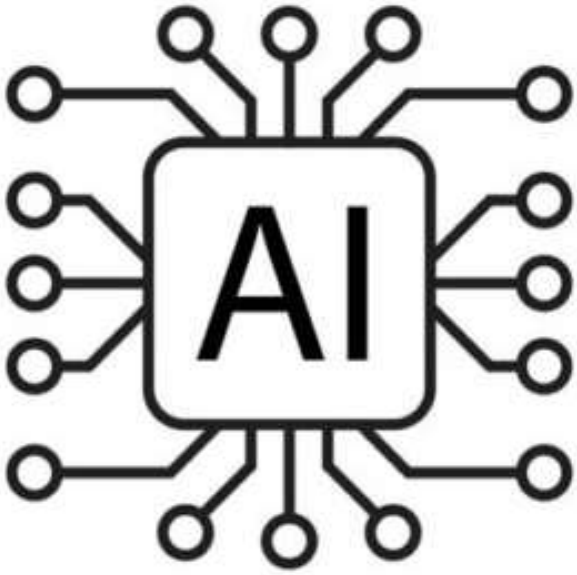
This magnificent building is still standing firmly on the same ground. But the respected people who once worked there are mostly gone now. Their offices have been sold and have, for the most part, been transformed into other businesses. The traditional businesses and crafts that once surrounded the creation and trade of hand-woven carpets are no longer the main activity of the Timcheh.

hat said, the city and its bazaar are still very much alive. Technology has transformed the carpet industry in remarkable ways. Computers have opened the door to spectacular new patterns and designs that would have been difficult, if not impossible, to create in the past. Modern industrial machines can now produce carpets of remarkably high quality, with extraordinary speed and precision, while keeping them affordable and accessible to a much broader population. Their efficiency, consistency, and ability to reproduce increasingly sophisticated designs have attracted many families, changing the way people think about carpets and encouraging them to bring these new creations into their homes.

In this sense, modern technology has fundamentally changed the traditional business model. What once required enormous amounts of time, skilled labor, and patience can now be produced on a large scale, with impressive quality and at relatively affordable prices. The carpet has, in many respects, moved from being a labor-intensive household or commercial craft to a highly efficient modern product, capable of reaching a mass market.

Ironically, however, the traditional hand-woven carpet industry has not disappeared altogether. It survives on a smaller scale, sustained by a limited number of highly skilled and dedicated artisans. Some of these rare professionals maintain their own galleries, where they create carpets that are no longer simply regarded as household objects or commercial goods, but as works of art. These exceptional hand-woven carpets may require months or even years of painstaking work and command extraordinarily high prices, affordable only to a very select class of people

Thus, the transformation is somewhat paradoxical. Modern technology has made beautiful, sophisticated carpets available to ordinary families at prices that would once have seemed unimaginable, while the traditional hand-woven carpet has moved in the opposite direction: from an everyday craft and commercial product toward a form of highly valued artistic expression. The carpet has therefore not simply disappeared with modernization; rather, it has divided into two very different worlds: one defined by technological innovation, mass production, affordability, and accessibility, and the other by craftsmanship, rarity, artistic value, and exclusivity.



With the profound changes brought about by the rapid emergence of AI in mind, it may now be clearer why I chose to tell this story. I see in it a striking parallel to our present concerns about the rapid emergence of AI and its growing presence in our academic departments.

There is little doubt that fundamental changes are already taking place, and that many more lie ahead. Our university campuses will certainly continue to stand for many years to come, and they may even retain structures that look surprisingly familiar. But what will our departments look like? How will our roles evolve? Will we see the emergence of highly specialized and sophisticated research universities, bringing together some of the world's leading scientists, alongside a growing number of universities increasingly focused on education and teaching rather than cutting-edge research? And what will become of the work, traditions, relationships, and human interactions that give our academic communities their distinctive character today?

P.S. All the photographs in this note were found on the internet and, to the best of our knowledge, none of them was accompanied by a copyright claim.

2027 CMS Summer Meeting, May 28-31 | Save the Date!

CMS Meetings



2027 CMS Winter Meeting, December 2-5 | Save the Date!

CMS Meetings





2026 CMS Winter Meeting, Dec 11-14 | Call for Mini Courses

CMS Meetings



The Canadian Mathematical Society (CMS) welcomes and invites proposals for mini-courses for the CMS Winter Meeting in Montreal from December 11-14, 2026.

Since 2019, the CMS meeting program has included a limited number of three-hour mini-courses with the following objectives:

- Initiating attendees to the subject of a novel scientific session, so as to broaden the scope of its audience and appeal; or
- Introducing attendees to a cutting-edge area of pure or applied mathematics, for both research and professional interests; or
- Providing professional development opportunities and advice, particularly for graduate students and new PhDs.

The CMS Winter Meeting mini-courses will be held Friday, December 11. Attendees will be charged a small registration fee.

All proposed sessions should be in line with the CMS Code of Conduct.

Proposals should Include:

(1) The names, affiliations and emails of the organizers. Each mini course is allowed one or two organizers per course.

(2) A title and a brief description of the focus and purpose of the mini-course, being particularly clear on how it meets one of the three objectives outlined above;

(3) A brief description of the anticipated mathematical background of the audience.

Deadlines

As the number of mini-courses is limited, please submit your proposal before October 16, 2026 via our online form.

Submit

2026 CMS MathEd Meeting (Online) | Call for Presentation Proposals

CMS Meetings



2026 CMS MathEd Meeting (Online)

The Canadian Mathematical Society (CMS) welcomes and invites education presentation proposals for its event, the 2026 CMS MathEd Meeting (Online) will take place on:

Friday, November 27th, 2026, (from 17:00 EST to 20:00 EST), and

Saturday, November 28th, 2026, (from 11:00 EST to 15:00 EST)

For this meeting, we will accept proposals on any theme in mathematics education

.

Education presentation proposals will be selected by the CMS Meetings Oversight Committee, which will also schedule the accepted sessions, in communication with their proposer(s).

Proposals should include:

(1) Names, affiliations, and contact information of the presenter(s). This is a fantastic opportunity for early career researchers and practitioners to propose presentations.
(2) A title and brief abstract of the presentation

All presentations will be of the standard CMS length: 20-minute presentations + 5-10 minute Q&A.

The deadline for the presentation proposals is Friday, October 2nd, 2026. There is a limited number of presentation spots. Preferences will be given to early submissions.

Please fill out the following Google form:

https://docs.google.com/forms/d/e/1FAIpQLSczo9UQKtwzOrEtH_qVAVki57yzi1RJkKDh86TBhLmZrQhUIg/viewform?usp=dialog

2026 CMS Winter Meeting, December 11-14 | Registration Now Open

CMS Meetings



2026 CMS Winter Meeting, December 11-14 | Registration Now Open

CMS Meetings



2026 CMS MathEd Meeting (Online) | November 27-28

CMS Meetings



Call for Nominations: 2026 CMS Excellence in Teaching Award

Calls for Nominations

The Canadian Mathematical Society is currently accepting nominations for the 2026 CMS Excellence in Teaching Award.

Deadline: November 15, 2026. No nominations will be accepted beyond this deadline.

The Excellence in Teaching Award recognizes sustained and distinguished contributions in teaching at the post-secondary undergraduate level at a Canadian institution. Nominations should include a nominating statement, a CV, and three letters of support; up to 10 pages of additional supporting material can be included.

Consult the CMS website for more information: https://cms.math.ca/awards/excellence-in-teaching-award/nomination-information/

2027 Math Competition Grants

Calls for Nominations

The CMS is currently accepting applications for the 2027 Competition Grants. In addition to hosting its own math competitions, the CMS offers math competition grants for activities at the elementary and secondary school levels. These grants are open to Canadian contests of different kinds at the school level. This includes:

- Traditional: students solve problems in a timed written exam
- Projects: Teams competing to solve a strategic problem over a longer period of time
- Posters: Preparation of a mathematical solution or discussion for display purposes

Deadline for applications: November 15, 2026

For more information, and to apply: https://cms.math.ca/education/competition-grants/application-information/

ICIAM Dianoia: Volume 14, Issue 3, July 2026

Announcements

ICIAM



Books Available From Teachers College Press

Announcements

University of Toronto Press



ICIAM Dianoia: Volume 14, Issue 3, July 2026

Announcements

We would like to share several upcoming opportunities with our student members!

Join the Studc – by November 30, 2026

We are looking for new members to join our team! If you are interested in contributing to the national-level programming for mathematics students, check out the free (or soon vacant) positions on Studc at Our Members – CMS Studc SMC and apply here. Currently we are looking for a new website editor, associate editor, vice-Chair (future Chair!), and Student representative on the CMS Academic Council to start in January 2027. Note that Studc members should be (able to become) CMS members.

Organize the 2027 CUMC – by November 30, 2026

We have officially opened the bids to host next year's Canadian Undergraduate Math Conference (CUMC)! Now is your chance to bring the CUMC to your institution!

You can find more information about organizing the CUMC and submitting a bid for the 2027 edition (including the full application instructions) on Studc's website. If you have any questions about the process, please don't hesitate to email us at cumc-ccem@cms.math.ca.

Contribute to the Notes from the Margin Journal – by October 1, 2026

Our student-run journal accepts research articles, expository pieces, math puzzles, reflections, and more! Shape our community by showing what is important to you today! More information can be found at Notes from the Margin – CMS Studc SMC.

Check out our **website** for more opportunities without deadlines!

Membership Ads

Memberships



