IMU News 129: January 2025

A Bimonthly Email Newsletter from the International Mathematical Union
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1. EDITORIAL: COMPUTER PROOF ASSISTANTS AND MATHEMATICS

A computer proof assistant, or an interactive theorem prover, is a programming language which is sufficiently expressive that it understands the concepts of mathematical theorems and proofs. Prototypes have existed since the 1970s but it was only this century that the systems became viable for tackling modern mainstream mathematics. The process of translating a normal (or "informal") paper proof into one of these languages is called "formalization".

In 2004 a team led by Georges Gonthier formalized a proof that all finite groups of odd order were solvable in the theorem prover Rocq (then called Coq); the original informal proof by Feit and Thompson was one of the reasons that Thompson was awarded a Fields Medal in 1970. Nowadays the work of many Fields Medallists have been formalized, mostly in the Lean theorem prover; examples include the Clausen—Scholze theory of liquid modules and the Gowers—Green—Manners—Tao proof of the polynomial Freiman—Ruzsa conjecture. The latter result was formalized in three weeks flat by a team of 25 people led by Tao, who has stressed the potential usage of such tools to harness large-scale collaboration in mathematics far beyond the usual two or three-author paradigm. Sidharth Hariharan, an undergraduate at Imperial College London, is currently leading a project with Viazovska to formalize the sphere-packing results which led to her award of the 2022 Medal. Bhavik Mehta has formalized several modern research results in combinatorics "in real time", and I am currently leading an EPSRC-funded project to formalize a modern proof of Fermat's Last Theorem.

But let us take a step back. In 2025 these systems are not doing mathematics autonomously; they are human-powered. It is difficult to learn how to use them, writing code takes time and proofs are far lengthier than they would be in LaTeX. So what is the point?

I offer two answers to this, both of which may make for uncomfortable reading. The first is that I believe that we are not as smart as we think we are. Over the last few years the mathematical formalization community have discovered mistakes in the literature, some serious, but all fixable (so far). We as a community know that the refereeing process leaves a lot to be desired, even at the top level. It is now commonplace in several areas of mathematics that breakthrough papers are long (over 100 pages is becoming the norm) and technical, and are clearly not being carefully read from cover to cover. Proof assistants offer a far more accurate way of doing mathematics, and as they mature and become more usable it will be interesting to see what else they uncover.

The second answer is that AI is coming for mathematics. However, language models remain frustratingly inaccurate on mathematics beyond school level, and one hallucination in the middle of a proof kills the argument. Google DeepMind's AlphaProof system is a language model trained to write Lean code; it autonomously performed at silver medal standard on the 2024 IMO, and things are moving very fast in this domain. A proof assistant/language model hybrid has the potential to eliminate confabulations. It will be very interesting to see what the future holds.

Kevin Buzzard
Department of Mathematics
Imperial College London

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2. ICM 2026: REGISTRATION NOW OPEN

Registration is now open for the International Congress of Mathematicians 2026, to be held in Philadelphia, Pennsylvania, USA, from 23 to 30 July 2026. Visit the registration page for details.

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3. INGRID DAUBECHIES AWARDED THE NATIONAL MEDAL OF SCIENCE

Ingrid Daubechies, James B. Duke Distinguished Professor Emerita of Mathematics and President of the IMU from 2011 to 2014, has been awarded the 2025 National Medal of Science, for her pioneering work on signal processing. The National Medal of Science is the highest possible recognition bestowed on scientists and engineers in the USA.

Daubechies has received numerous awards, including the ICIAM Pioneer Prize (2007), the Steele Prize for Seminal Contribution to Research (2011), the William Benter Prize in Applied Mathematics (2018), the Fudan-Zhongzhi Science Award (2018), the L'Oréal-UNESCO International Award For Women in Science (2019), the Princess of Asturias Prize for Technical and Scientific Research (2020), and the 2023 Wolf Prize in Mathematics. She is a member of the American Academy of Arts and Sciences, the US National Academy of Engineering and the US National Academy of Sciences.

For further details, readers are referred to this page and this page.

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4. 2024 ABEL PRIZE INTERVIEW

The 2024 edition of the traditional Abel interview is now available: read the interview with the 2024 Abel Prize laureate Michel Talagrand on this EMS page, and watch the video made available on the Abel Prize YouTube channel.

On a related note, we remark that the fourth book in the Abel Prize series, presenting the Abel Prize Laureates, has been published, and is available on this page of the Abel Prize website for download for free. This edition covers the years 2018–2022.

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5. 2024 SHAW PRIZE LECTURE

Readers are invited to watch the 2024 Shaw Prize Lecture in Mathematical Sciences, delivered by the 2024 Shaw Prize laureate Peter Sarnak on the Shaw Prize YouTube channel. The channel also features the series *Mathematical Insights: Conversation with Professor Peter Sarnak*, among a wealth of material related to the prize.

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6. 2025: INTERNATIONAL YEAR OF QUANTUM SCIENCE AND TECHNOLOGY

The United Nations General Assembly, on 7 June 2024, proclaimed 2025 as the International Year of Quantum Science and Technology (IYQ) under the auspices of UNESCO. According to the proclamation, this year-long, worldwide initiative will "be observed through activities at all levels aimed at increasing public awareness of the importance of quantum science and applications."

An opening ceremony will be held by UNESCO to inaugurate the IYQ on 4 February 2025, celebrating its importance in building a resilient and sustainable future.

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7. NEWS FROM THE INTERNATIONAL COMMISSION ON MATHEMATICAL INSTRUCTION (ICMI)

Reports from ICME-15 Survey Groups. During the last International Congress on Mathematical Education ICME-15 in Sydney in July 2024, one of the activities concerned four survey groups. ICMI is happy to present here a short report on the work of those four groups. Thanks are due to Susanne Prediger, who obtained from the respective chairs the reports presented below.

Survey teams are commissioned by the IPC to examine new developments and progress on specific themes and issues that have arisen in mathematics education during recent ICMEs. Survey teams identify and characterize important new knowledge, recent developments, new perspectives, and emergent issues, and each team reports their findings and recommendations at the Congress.

ICME Survey 1 – Challenges and perspectives of mathematics assessment

Survey team: Kaye Stacey, University of Melbourne (Australia), team leader; Yuriko Yamamoto Baldin, Universidade Federal de São Carlos (Brazil); Kim Koh, University of Calgary (Canada); Ruhama Even, The Weizmann Institute of Science (Israel); Ross Turner, The Australian Council for Educational Research (Australia); IPC Liaison: Olive Chapman

The survey focused on formative assessment conducted by classroom teachers as part of the teaching-learning-assessment cycle, aiming to provide information for teachers and/or learners to use in upcoming lessons. We distinguish assessment from teachers' normal continuous monitoring of students' understanding by some formality to the process (e.g., by recording results).

When systematically surveying 105 papers on **teachers' use of formative assessment and teaching noticing** for informing short-term instructional decisions, Ruhama Even found similarities, but also a surprising disconnection of the areas, and an important absence: teachers' responses and acting on evidence of students' learning are rarely studied in real classrooms.

In a sweeping survey of **how learning progressions are used in assessment**, Ross Turner found multiple kinds of learning progressions, which vary in scope (from single concepts to whole domains) and approaches to their development and underlying measurement models. He documented promising ways to organize formative assessment along different learning progressions to help identify learners' current knowledge, describe and report learning progress, guide teachers in the selection or development of suitable teaching and learning resources, and also support teacher professional learning. More support is required for teachers to adaptively enhance their learners' knowledge.

When systematically surveying the **assessment of higher-level mathematics thinking competencies** (including 21st century competencies), Kim Koh found that many curricula now highlight deeper mathematical understanding with competencies such as critical thinking, creativity, collaboration, and communication. Yet, questions remain about how students' competencies are assessed and what form assessments can take, how cognitive and affective aspects are included and how more authentic settings for assessments are achieved.

Through an open call to educators mainly in South and Latin America, Yuriko Yamamoto Baldin received 38 reports on **teacher education about assessment**. Most respondents noted the lack of cohesion between curriculum demands, national assessment policies and the reality of classroom formative assessment practices and saw a strong need to better prepare teachers for them, in particular for 21st century competencies. Respondents generally identified challenges posed by the outcomes of external large-scale assessments with uniform ranking criteria that do not take local cultural, political and educational contexts into account.

Finally, a brief overview of some of the major changes to **assessment within the teaching-learning cycle that are implemented using new technologies** was given by Kaye Stacey. The changed conditions of school and university education imposed by the pandemic greatly accelerated these changes. She gave an example of how a computer-algebra based assessment tool is providing students in extremely large classes in an under-resourced country with regular mathematically-detailed feedback on their individual work and as many opportunities for practice as they wish, usually on mobile phones. Formative assessment like this has

never previously been possible and may change the mathematics learning experience of millions of students around the world.

Further details relating to all these contributions are available from the authors.

ICME Survey 2 – Mathematics education and Indigenous perspectives

Survey Team: Florence Glanfield, University of Alberta (Canada), team leader; Maria del Carmen Bonilla, Universidad Peruana Cayetano Heredia (Peru); Albert Henry Ntarmah, University of Alberta (Canada); James Nii Boye Bannerman, University of Alberta (Canada); IPC Liaison: Chris Matthews

Indigenous peoples (IPs) represent about 6.2% (476.6 million) of the world's population, living across the globe. The UN have a working definition of IPs, centered on three primary elements: (1) a pre-colonial presence in a particular territory, (2) a continuous cultural, linguistic, and social distinctiveness from the surrounding population, and (3) a self-identification as 'Indigenous' and recognition by other Indigenous groups as 'Indigenous'.

The survey team first conducted a systematic literature review to explore mathematics education and indigenous perspectives. Our search strategy revolved around two main themes: mathematics education and Indigenous perspectives, and then around the concept of Indigeneity. The literature review was limited to articles published in English and Spanish. We briefly summarize our findings of the systematic literature review, organized according to geographic regions.

From Oceania (including Indigenous peoples such as, e.g., Māori of New Zealand, Aboriginal and Torres Strait Islanders of Australia, Kanaka Maoli of Hawaii, and many others), we found 75 articles published between 1987 and 2023. The four most common themes were: incorporating cultural and Indigenous perspectives, knowledge, and practices in mathematics education; culturally responsive pedagogies and place-based mathematics education; the role of traditional counting systems and Indigenous mathematics in developing numerical cognition and mathematical understanding; and language and discourse in mathematics education for Indigenous and multilingual learners.

From Asia (including Indigenous peoples such as Tibetans and Uighurs of Western China, Ainu of Japan, Adivasi of India, Hmong of Thailand and others), we found 31 articles published between 1993 and 2022. The four most common themes were: historical perspectives on mathematics education; Indigenous mathematics and ethnomathematics; decolonizing mathematics education and incorporating Indigenous knowledge; and mathematics learning and cultural identities in Asian contexts.

From Europe (including Indigenous peoples such as Sámi of Scandinavia, Basques of Spain and France), we found 25 articles published between 2000 and 2023. The three most common themes were: Sámi values and culture in mathematics education; Sámi braiding (ruvden) and its use in teaching discrete mathematics; and language diversity and cultural context in mathematics education.

From Africa (including, among others, San of Southern Africa, Pygmies of Central Africa, Amazigh of North Africa), we found 33 articles published between 2003 and 2022. The four most common themes were: incorporating Indigenous games and cultural artifacts into mathematics teaching; exploring mathematical concepts embedded in Indigenous cultural practices; integrating Indigenous knowledge systems and

ethnomathematics into mathematics curriculum; and decolonizing mathematics education and embracing Indigenous epistemologies.

From Latin America and the Caribbean (including, among others, Maya of Central America, Aymara of Andeans, Guarani of Paraguay, Taíno of Puerto Rico), we found 52 articles published between 2014 and 2024 in English and Spanish. The four most common dimensions were political, teacher training, mathematical, and sociocultural.

From Northern America (including, e.g., Navajo of Southwest, Cherokee of Southeast, Cree of Central Canada, or Inuit of Arctic regions), we found 97 articles published between 2000 and 2023. The four most common themes were: culturally responsive and place-based mathematics education; integrating Indigenous knowledges, cultures, and perspectives in mathematics education; decolonizing mathematics education and addressing the colonial legacy; and addressing inequities and promoting access and success in mathematics for Indigenous students.

This geographical representation of the number of articles published in English and Spanish over the past 40 years suggests an increasing interest in the intersection of Indigenous peoples' experiences, cultures, and knowledge systems within the field of mathematics education.

Based on the preliminary analysis completed, which introduced concepts of different dimensions related to Indigenous mathematics, the survey team, led by Maria, will work together to prepare an electronic survey of researchers in the fields of Indigenous mathematics, ethnomathematics, and other intersecting areas. The survey will be available in multiple languages as we recognize the limitation of this literature review.

ICME Survey 3 – Statistics and data science education as a vehicle for empowering citizens

Survey Team: Rolf Biehler, Paderborn University (Germany), team leader; Takashi Kawakami, Utsunomiya University (Japan); Erna Lampen, Stellenbosch University (South Africa); Travis Weiland, University of North Carolina at Charlotte (United States); Lucia Zapata-Cardona, Universidad De Antioquia (Colombia); IPC Liaison: Katie Makar

School statistics has not kept pace with how citizens engage with increasingly ubiquitous data, such as navigating X-feeds, using artificial intelligence (AI) to identify photos, or how personal data is collected by social media and recommender platforms. Data science and data-driven AI have led to breakthroughs in science and society; however, such breakthroughs come with ethical concerns, creating a need to redefine how to empower citizens through statistics and data science education. The survey identified different pedagogical approaches for civic education, including critical statistical literacy, civic statistical literacy and data-driven mathematical, computational and algorithmic modeling, as well as more general data literacy, and critical data literacy. Recent books, articles, and special issues in statistical education and general education journals were reviewed.

When reviewing **civic statistics and humanistic perspectives on data literacies education in the U.S. and Europe**, we found that transdisciplinary themes have been prevalent for several years. Small-scale qualitative projects infused data literacy across the curriculum in (1) reading the world with data, making sense of others' data-based communication, including data viz and data journalism; (2) writing the world with data, using data practices to investigate the world around us, with students authentically engaging in

the activities of the discipline through data investigations or creating data stories; (3) data structures and handling; and (4) technology, including developing, interacting with, and learning from technology.

When reviewing **critical perspectives on data literacy emerging from Latin America**, we found that critical data literacy, a skill set that enables people to use and produce data critically, with technical skills and reasoning at the intersection of data and context, is being promoted. In this region with high levels of social, cultural, and economic inequality, critical data literacy has been identified in research on school education as essential to making sense of the data that affects people's lives, to make informed decisions, to participate in public life, to expose systematic social injustices and to develop awareness of social issues.

When reviewing **joint discourses between mathematical modeling and statistics/data science communities**, we found that research at the interface of mathematical modeling and data science is increasing with three different discourses: (1) data-rich mathematical modeling processes are promoted with statistics and mathematics at their core to develop statistical and/or mathematical literacy and/or disciplinary learning, (2) interdisciplinary data-rich mathematical modeling to promote STEM literacy, (3) societal data-rich mathematical modeling using global, social, political, ethical, and everyday contexts to promote critical thinking and citizenship. All three discourses emphasize the cyclical nature of modeling and explore the relationship between discipline-specific approaches to modeling and the role of data in this.

When surveying **what mathematics/statistics education can contribute to artificial intelligence/machine learning literacy**, we found that the discussion of AI literacy for secondary school students has expanded rapidly over the past few years. Machine learning involves predicting outcomes through mathematical and statistical modeling and a broader form of inference than sample-to-population inference. At least one type of machine learning should be taught in schools using a white or grey box approach, with decision trees and *k*-nearest neighbors as promising candidates. Understanding types of misclassification and differentiating between training and test data to address overfitting, bias, and fairness are important components. Research projects have been identified that make these concepts accessible to secondary school students through tools such as data cards, CODAP, and Jupyter notebooks.

We conclude that this review clearly indicates that statistics has evolved into data science with new tools, discourses, and various application domains. The data demands that pervade most societies require renewed attention to statistics education at school, data science education across disciplines, and research-informed decisions about curriculum and pedagogy.

The publication of a longer version of this report is under preparation. For a pre-order, please send an e-mail.

ICME Survey 4 – Interdisciplinary exchange among Mathematics Education and Neuroscience

Survey Team: Roza Leikin University of Haifa (Israel), team leader; Hui-Yu Hsu, National Tsing Hua University (Taiwan); Daniel Ansari, Western University (Canada); Dor Abrahamson, University of California (USA); Andreas Obersteiner, Technische Universität München (Germany); Maayana Miskin, University of Haifa (Israel); Ilana Waisman, University of Haifa (Israel); IPC Liaison: David Gomez

Our team performed a systematic survey of empirical studies that employ neurocognitive methods in research focusing on mathematical learning, development and problem solving. The survey was aimed at tracing major trends of cognitive neuroscience research linked to mathematics education. In particular, we

asked (a) How can the distribution and development of studies that integrate **Mathematics Education** and **Neuroscience** be characterised over time? (b) Which neuroscientific tools are used in studies linked to Mathematics Education? (c) Which mathematical topics/concepts are examined using the different tools? (d) How are the topics distributed? (e) Which are the general trends observed through the survey and which recommendations can be made for the future development of research that integrates Mathematics Education and Neuroscience?

Following the procedures of systematic surveys the research was performed in 3 stages: identification, screening, and analysis. Identification of relevant publications was conducted using the EBSCO discovery system. The screening stage followed restrictions of the empirical studies published in English-language research journals. Of a total of 35,692 records that were identified initially, 598 papers were found eligible for precise data analysis through the screening procedure. We performed bibliometric and content analysis through employing descriptive and visualization network approaches. Our findings show a clear increase over the past 20 years in research combining Neuroscience and Mathematics Education.

The fMRI, EEG and Eye-tracking are the neuroscience tools most often used in this research. Neuroscience research on mathematical cognition has revealed insights into how our brains process, learn, and solve mathematical problems. These studies help explain individual differences in mathematical abilities and problem-solving skills. While researchers have used neuroscientific methods to examine a variety of mathematical topics and skills, the studies focusing on arithmetic objects and operations are the most frequent. At the same time, some branches including probability theory and advanced mathematics remain understudied.

Research methods in mathematical cognition have evolved over time, from established techniques like fMRI and brain mapping to eye-tracking focusing mathematical reasoning. The field has progressed from studying numerosity and dyscalculia to exploring complex processes like algebraic thinking and problem-solving. Importantly, neurocognitive tools reveal that similar behavioral outcomes can stem from different neural processes – insights that traditional behavioral research alone cannot provide. This demonstrates the unique value of neuroscience in understanding mathematical thinking and its relationship to broader cognitive abilities.

Still current research in mathematics neurocognition has significant gaps: it focuses mainly on basic mathematical skills while neglecting advanced topics like calculus, and rarely examines domain-general cognitive traits. Additionally, most findings are published in neuroscience rather than education journals and thus mathematics educators may miss important developments. Future research should: (1) develop better tools to study diverse mathematical content and competencies, (2) establish rigorous methodologies specific to mathematics education as neurocognitive tools become more accessible, and (3) investigate how classroom dynamics and cognitive mechanisms influence mathematical learning. This interdisciplinary approach could help educators better understand and address individual differences in mathematical processing.

Jean-Luc Dorier
ICMI Secretary General

8. NEWS FROM THE COMMISSION FOR DEVELOPING COUNTRIES (CDC)

The next International Congress of Mathematicians will take place in Philadelphia, USA, from July 23 to 30, 2026. The call for applications for the ICM 2026 Travel Support Program, which provides financial support to mathematicians from eligible developing countries to attend, is now closed. The program received an impressive number of applications from across all continents. Applicants will be notified of the results in the spring of 2025.

We would also like to remind you about our new IMU-Simons Research Fellowship Program for Developing Countries, generously funded by the Simons Foundation. This new grant program supports mathematicians based in developing countries in undertaking collaborative research at mathematical institutions abroad. The CDC strongly encourages mathematicians and students from developing countries to apply to our calls listed below and to contact us for further details via email.

Grants for institutions

- Volunteer Lecturer Program (next deadline March 1, 2025, for courses to be held between August 1, 2025, and August 1, 2026)
- Library Assistance Scheme (no fixed deadline)

Grants for conferences organizers

- Conference Support Program (next deadline April 15, 2025, for conferences starting after August 15, 2025)

Grants for research visits

- Abel Visiting Scholar Program (next deadline April 30, 2025, for research visits between September 1 and December 31, 2025)
- IMU-Simons Research Fellowship Program for Developing Countries (next deadline April 15, 2025, for research visits starting between August 15, 2025, and August 15, 2026)

Grants for graduate students

- IMU Breakout Graduate Fellowship Program (the 2025 call for nomination will open no later than March 1, 2025)
- Graduate Research Assistantships in Developing Countries (GRAID) Program (the 2025 call for applications is open with deadline on March 15, 2025)

Ludovic Rifford
Secretary for Policy of the CDC

9. NEWS FROM THE COMMITTEE FOR WOMEN IN MATHEMATICS (CWM)

CWM Newsletter Issue 12 – December 2024. The CWM closed 2024 with the release of the 12th issue of its newsletter. In addition to several news and announcements, the newsletter includes an interview with CWM member Catherine Greenhill, from Australia, and the article "Inception of Asian-Oceanian Women in Mathematics (AOWM) and Its Progress in Last One and Half Years", which will also appear in the upcoming proceedings of the second edition of the World Meeting for Women in Mathematics – $(WM)^2$ 2022.

The newsletter can be downloaded here and you can subscribe to the CWM Newsletter here.

Result of CWM Call 2025. The CWM 2025 call received 61 applications, of which 13 will be supported. Some of the selected projects aim to support continental and regional networks for women in mathematics, such as activities led by the African Women in Mathematics Association (AWMA), the Meeting of Women in Mathematics in Central Africa in Congo, and the establishment of the Arab Women in Mathematics Network. CWM is also supporting research workshops aimed at establishing research networks for women in Brazil, Indonesia, Mexico, and Nigeria. Additionally, CWM is supporting networking activities for women in mathematics in Argentina, India, Kenya, Nigeria, and Zimbabwe, as well as a math camp for young women in Iran. Depending on the nature of the project, CWM funding is directed toward infrastructure, travel expenses, and accommodation support for women participants from developing countries. The complete list of selected projects can be found here.

SCGES Webinar – Women scientists around the world: strategies for gender equality. On February 10th, 2025, the SCGES, Standing Committee for Gender Equality in Science, will host its 12th Webinar, *Women scientists around the world: strategies for gender equality*, organized jointly with the International Science Council. The webinar will take place online 14:00–16:00 UTC, and it is SCGES' contribution to the Global Women's Breakfast.

More information and a registration form can be found on the SCGES Webinar Series webpage.

SCGES was established in September 2020, with the IMU and ICIAM – International Council for Industrial and Applied Mathematics – among its founding members. Since 2022, the regular SCGES Webinar Series has highlighted various topics of interest around the focus tasks of the committee.

Carolina Araujo and Hélène Barcelo
Chair and Vice-Chair of the IMU Committee for Women in Mathematics

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10. NEWS FROM THE INTERNATIONAL DAY OF MATHEMATICS (IDM)

1. Betül Tanbay (Boğaziçi University) is replacing Christiane Rousseau as Chair of the IDM Governing Board (IDMGB) for the period 2025–2029. Christiane Rousseau will continue to advise the board. The other new members of the IDMGB are Suely Druck (Brazil), Bruny Mabien (Haiti) and Carlene P. C. Pilar-Arceo (Philippines).

2. The Math you can Touch 2025 Creative Challenge is now online: It involves constructing mathematical elements using everyday physical objects (such as household items, objects from nature, or even people).

3. The IDM Governing Board needs your help to spread the news of IDM in national and local school networks and increase the number of schools celebrating the IDM, either in the classroom, or through a larger event. For that purpose, material for classroom activities is available. Invite the school networks of your country using the following invitation letters:

Arabic — English — French — German — Portuguese — Spanish — Turkish

If you wish to produce a letter in your own language, you can use the following English template.

4. The 2025 IDM map is now open for posting. Please invite any organizer of an IDM celebration, including the celebrations taking place in schools, to publish their event on the IDM map by filling this form.

5. Visit the activity page for suggestions of activities. In particular there will be a lunar eclipse occurring on March 14, 2025, and it will be visible from half of the world and all the Americas. Hence, you will find an activity on the mathematics of eclipses. Another activity will explain how to draw artistic tilings. Posters, pins and logos can be found at our resources page. In particular the 2025 IDM poster will be available soon.

6. A joint IMU-IDM-UNESCO Webinar, *Mathematics and creativity in Art and Education*, will take place on March 14, 2025, 13:00–14:30 UTC.

7. Subscribe to the IDM Newsletter to receive the latest news of IDM 2025.

Betül Tanbay
Chair of the IDM Governing Board

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11. SUBSCRIBING TO IMU NEWS

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