

## Joining Forces in International Mathematics Outreach Efforts

*Diana White and Alessandra Pantano, et al.*

Participants at a Banff workshop launch Mathematics Outreach International.

### Introduction

Valuable and innovative mathematical outreach activities are being held all over the world and have proven to be successful in creating interest in mathematics and spreading awareness of its importance to society. However, despite the international nature of mathematics, the majority of outreach activities never cross the borders of the countries where they are initiated, and in some cases never go beyond their immediate local community. Many of these outreach activities may be beneficial to audiences in other countries, and it is in everyone's interest to find ways to share our resources and expertise and create the means for wider dissemination of successful outreach efforts.

In November 2015 a group of eighteen mathematics outreach specialists converged at the Banff International Research Station (BIRS) in Alberta, Canada, for an international math outreach workshop. The participants included academic faculty from both local and world-renowned institutes and universities, graduate students, program directors, journalists, and filmmakers. Coming from Australia, Canada, Denmark, France, Germany, the United Kingdom, and the United States, they presented examples of their outreach work and engaged in lively discussions about future international collaboration. Participants provided a variety of perspectives and expertise; the spectrum of nationalities further contributed to the richness and diversity of experiences and initiatives on display. They reached agreement on the need to develop an international networking infrastructure for outreach and explored the possibilities of both expanding existing activities and creating new ones. Cédric Villani, Fields Medalist, joined the conversation through Skype; he explained his view of



**International Math Outreach Workshop participants at the Banff International Research Station (BIRS).**

the importance of reaching outside the mathematics community and talked about his own involvement in outreach.

One theme that clearly emerged from the discussions is that outreach initiatives across the world have much in common, most notably goals and inspiration. They also face similar challenges, such as recognition of the involvement of researchers/professors from academic institutions and the realization by policymakers and journalists of the importance of mathematics. Workshop participants compared strategies and solutions for addressing these challenges as they sought to define ways to expand outreach initiatives, with particular attention to gender issues and developing countries; to facilitate cross-country collaborations; and to introduce a certain level of international coordination.

Attendees addressed the many important reasons for conducting mathematical outreach, from a simple desire to inspire people to share a love of mathematics

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to the need to spread recognition in the wider public and among policymakers of the importance of mathematics in our general understanding of crucial questions for our societies (climate change, limited supply of fossil fuel, etc.). Discussion rapidly led the participants to understand the need to:

- join forces to develop international strategies to eliminate false perceptions about mathematics,
- better exploit the imagination and ingenuity of many ongoing local outreach efforts by sharing resources on the international scene,

organize mathematics outreach meetings and pool forces around a new international mathematics outreach initiative, and

- develop mathematics outreach activities in the developing world.

In the remainder of this article we discuss some of the global goals of mathematical outreach, give highlights of interesting specific outreach efforts in various countries presented at the workshop, and end with a discussion of plans for a new Mathematics Outreach International (MOI).

### **Why Is Mathematical Outreach Important?**

Mathematics is an intricate part of everyday life. This is not well understood by large portions of the general public or by policymakers, students, and teachers. Mathematical outreach efforts aim to foster favorable attitudes towards mathematics and to develop a broader awareness of mathematical culture by promoting an understanding of the fundamental role of mathematics in the world. Outreach efforts also seek to enhance the enjoyment of the learning of mathematics.

We know that mathematics is a way for people to access and develop skills such as critical thinking, problem solving, and perseverance and that outreach has the ability to convey solid role models for careers in science, technology, engineering, and mathematics (STEM). It is therefore important that outreach efforts also be aimed at underrepresented groups in education known to



**Graduates of the 2013 PIMS Summer Math Camp for Aboriginal students.**



**Seminar on normal numbers during a 2014 summer camp at Laval University for a group of college students in mathematics.**

disengage with mathematics (and other STEM disciplines) at a higher rate than the rest of the community.

Institutions of higher education strive to advance learning and to create and disseminate knowledge in society. Thus outreach to the public, to students, and to teachers is an essential component of this mission. Universities then must be among the principal actors in outreach efforts. However, outreach is also a responsibility of the whole mathematical community. There are still too many people who mistakenly envision mathematics as a dead science, in the sense that everything that needed to be discovered in mathematics has already been discovered, or who regard mathematics as a science reserved for the elite or something incredibly difficult and therefore not accessible to everyone. Others simply doubt the relevance of mathematics to the daily lives of most people. By joining forces in outreach initiatives, the mathematical community can develop strategies to eliminate these false perceptions and increase appreciation for mathematics and for its fundamental role in culture and society. Specific outreach efforts may vary significantly in terms of their intended audience as well as their goals. To emphasize the variety, we present some of the outreach initiatives that were outlined and discussed at the BIRS workshop.

### **Fostering Talent—Competitions and Intensive Programs**

Many countries have a culture of mathematical competitions intended to foster talent, with some of the best culminating in participation in the International Math Olympiad. Other kinds of competitions exist, where the focus is on long-term collaborative work rather than on test taking, bringing them closer to a research experience. Some are multidisciplinary, like the US-based Intel Science Talent Search, the German Jugend Forscht, or the European Union Contest for Young Scientists. Others are purely mathematical, like the International Tournament of Young Scientists and its national counterparts: the French Tournoi Français des Jeunes Mathématiciens, the Quebec tournament organized by the Association Québécoise des Jeux Mathématiques, and the recently started Brazilian Torneos de Matemáticas para Jovens.

Other programs aim to develop mathematical talent locally, focusing on research more than on competition. For example, the Program in Mathematics for Young Scientists (PROMYS) at Boston University provides a six-week immersive research experience for mathematics majors, high school students, and teachers. In its 27-year history, the PROMYS program has had a remarkable impact on developing mathematical habits of mind in its participants: 277 PROMYS alumni, including 70 women, have, or are currently working on, a PhD in mathematics. In Europe, the Russian Contemporary Mathematics Summer School in Dubna has been organized since 2001; a similar program, Modern Mathematics, has been held in Bremen or Lyon every year since 2011.

### Discovering New Mathematical Talent

Engaging students directly in mathematics is a powerful strategy. Research shows that often students who struggle in standard classroom settings may come alive and prosper in informal mathematical activities. Math fairs play an exceptional role in generating enthusiasm towards mathematics. Notable examples include the National Math Festival and the Gathering4Gardner conference in the United States. In France the MATH.en.JEANS program organizes research projects for middle and high school students that are mentored by a research mathematician. Online platforms containing free resources for potential hosts of mathematical events are flourishing in many countries. An example is the Celebration of Mind website, which provides a repository of intriguing mathematical activities (toys, puzzles, magic tricks, and games) for teachers, students, parents, and math enthusiasts of all ages, or the IMAGINARY participatory project and website, hosting exhibitions and other mathematics material.

A number of specialized mathematics museums have been created around the world, like the Mathematikum in Giessen, Germany; the National Museum of Mathematics (MoMath) in New York, USA; and the Giardino di Archimede in Florence, Italy. Organized visits by school children to those museums have demonstrated their impact.

### Fostering In-depth or Sustained Engagement

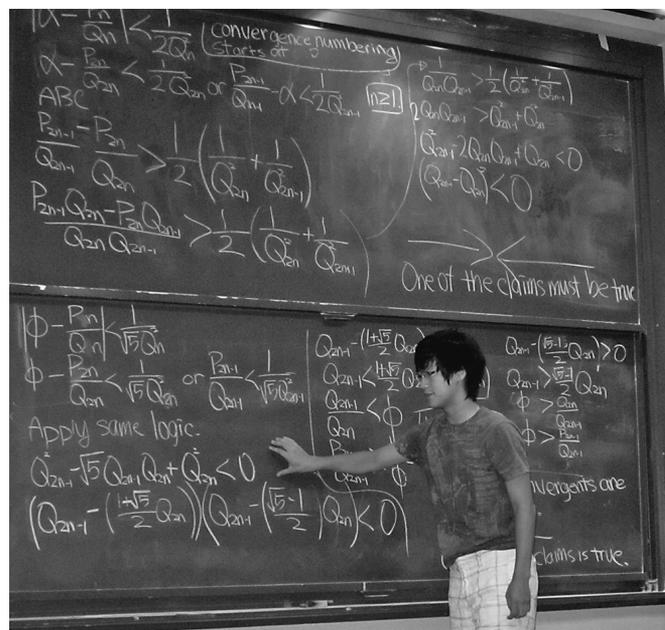
Frequent sessions of mathematical investigations are key to engaging young math enthusiasts in the process of mathematical discovery, which also promotes a deeper understanding of mathematics. Originating in the Eastern European tradition, these activities are currently organized weekly or monthly throughout the world under the name of Math Circles in the United States and Eastern Europe, Maths Masterclasses in the UK, circles or clubs in France, et cetera. The programs promote independence and creativity within a supportive community.

### Fostering Social Justice—Democratizing Access to Mathematics

In mathematics-related studies and careers, some groups participate at a much lower rate than others. Examples include indigenous communities, students from language backgrounds other than the predominant language of a country, and young people from low socio-economic backgrounds. Engaging these traditionally underrepresented groups in mathematical outreach initiatives can boost their participation in higher education and STEM careers.

The University of California Irvine, Math Community Educational Outreach is an outreach program aimed at underserved youth, with the dual scope of encouraging children to attend college and providing the mathematical and critical thinking skills necessary to succeed. About one hundred middle school students from local disadvantaged communities visit weekly after school to work on original, thought-provoking mathematics in a small group setting together with a team of Irvine faculty and students. The same kids, along with their parents, participate in a STEM-day at Irvine to learn about the fascinating research taking place “just down the road,” explore careers in STEM, and get a taste of college life. Additional meetings are hosted at local schools to provide parents with information concerning college opportunities and financial aid for their kids, and because the schools are 98 percent Hispanic, all the communication is provided in both English and Spanish. The San Francisco Math Circle is another example of a program aimed at urban youth. In France, contrary to the United States, the majority of socially disadvantaged families live

*Engaging students directly in mathematics is a powerful strategy*



At the end of each summer, students present their independent work to the entire PROMYS program.

in the suburbs. The MathC2+ program organizes math camps geared towards these suburban youths.

### Addressing Gender Issues

Mathematics remains a predominantly male profession in most countries, and the same is true for many STEM career paths. The adverse effect of gender stereotypes on mathematics performance has been clearly demonstrated. Specific programs have been developed to address gender issues in mathematics, like the “Girls and mathematics, a shining equation” day of events organized in France.

The participation of girls in national and international olympiads is low. To address this problem, specific competitions for girls, like the European Girls’ Mathematical Olympiad, have been created. However, gender imbalance remains a great source of preoccupation; perhaps a diversification of the kinds of competitions offered could provide a remedy.

### Mathematics Outreach in Developing Countries

By the end of the twenty-first century, it is expected that nearly half of all babies will be born in Africa. The challenge of providing a good STEM education in developing countries is tremendous. For similar reasons as in affluent countries, getting students interested in mathematics cannot wait until they reach college. Some instruments successfully used in affluent countries, such as math circles and clubs, competitions, and mathematics exhibitions, should be fostered in developing countries as well, with help provided by mathematicians and mathematics educators from around the world.

### Increasing Mathematical Literacy among Policymakers and Citizens Alike—Tools to Popularize Mathematics

It is recognized that mathematics plays a fundamental role in our society and culture, here considered in the broad sense to include art, literature, and science. Mathematics provides the necessary tools for scientific thought. For example, the impossibility of sustaining exponential growth in a context of limited resources is certainly pertinent to the understanding of the concrete limits of our continued use of fossil fuels. Other examples include an assessment of risk in health or the impact of social decisions.

Tools for popularizing mathematics include websites, classroom materials, films and books about mathematics and mathematical personalities, theatrical performances, public lectures by prominent mathematicians, radio and television programs, and exhibitions at museums and in other public settings. We discuss two films that were shown during the BIRS workshop in more depth here.

The first, a screening of Olivier Peyon’s prize-winning 2013 feature documentary *Comment j’ai détesté les maths* (*How I Came to Hate Math*) sets out to display the public’s ambivalence to mathematics and goes on to present the importance of the subject to various human activities, particularly finance. Celebrity mathematicians such as Jean-Pierre Bourguignon, Robert Bryant, Jim Simons, and Cédric Villani are summoned at various points of the movie to convey their thoughts on the relevance of mathematics



**Navajo students make a discovery at math camp in *Navajo Math Circles* (2016), a film by George Csicsery, supported by MSRI, Vision Maker Media, and the Simons Foundation.**

in everyday life and to shed light on the beauty of this field and its role in seeing deeper structures in the world.

The second, *Navajo Math Circles*, a one-hour film produced in 2016 by George Csicsery, MSRI, Vision Maker Media, and the Simons Foundation, documents a three-year project that has brought math circles to a number of schools on the Navajo reservation in the southwestern United States. The project and the film seek to show how the mathematics introduced at a Navajo math camp can be combined with cultural components from the indigenous community to enhance mathematics education and, more broadly, education as a whole for underserved populations.

Mathematics-themed films in the public and private television environment face a variety of challenges. The expansion of social media platforms such as Facebook and Twitter favors production of shorter, high-impact video pieces, while long-form documentary delivered over television is becoming much less prominent. The Web, however, does provide space for longer in-depth productions, such as the *Science Lives* biography series embarked upon by the Simons Foundation in 2010, which now hosts over 90 hours of oral histories with mathematicians telling their own stories.

### Samples from the International Landscape

The BIRS workshop showcased a rich and varied sampling of outreach initiatives currently being carried out in many countries. There are many commonalities, such as public lectures, mathematics enrichment sessions for school children, competitions, museum exhibits, movies, and theater performances. Without trying to be exhaustive, here are a few brief examples of national outreach activities presented by BIRS workshop attendees.

**Australia Mathematical Sciences Institute:** The Australia Mathematical Sciences Institute (AMSI) is engaged with the entire mathematics education pipeline: It develops materials for school-grade mathematics, trains teachers, organizes career workshops for university students, places PhD students in industry internships, plans public events



**Cédric Villani at the Fields Medal Symposium Public Lecture for Students and Undergrads 2014.**

young mathematics enthusiasts, while the Mathematics Millennium Project, based in Cambridge, promotes several initiatives to increase mathematical understanding, confidence, and enjoyment, including visits to schools and Internet-based resources such as problem listings and a mathematics magazine.

**United States:** The United States has a decentralized structure for mathematical outreach, with efforts led locally at schools and higher education institutes by the major mathematical organizations, such as the American Mathematical Society, the Mathematical Association of America, the Society for Industrial and Applied Mathematics, and by major mathematics research institutes, such as the Mathematical Sciences Research Institute and the American Institute of Mathematics. Efforts include competitions, exhibits, festivals, math days, math circles, math camps, films, and books. An increasing number of initiatives are aimed at underserved youth. Practitioners share resources informally; over the past decade it has become common for major national mathematics conferences, such as the Joint Math Meetings and MAA Math-



**Students working together at the Summer Rocky Mountain Math Student's Circle Workshop.**

Fest, to have special sessions related to outreach where participants present program information, resources, best practices, and lessons learned. Across higher education institutes, support for outreach activities varies widely. While many are active supporters, some still actively discourage graduate students and faculty from partaking.

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*Cooperation  
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### **Current Examples of International Collaboration**

Levels of coordination within and across countries vary greatly from one-off small local projects to large annual national and international projects featuring a range of events. In this section we discuss the successful Mathematics of Planet Earth Year in 2013 and the IMAGINARY platform for open and interactive mathematics.

**Mathematics of Planet Earth.** The Mathematics of Planet Earth (MPE) initiative illustrates a successful international outreach collaboration that models how cooperation can produce a synergistic effect. Using their own resources, a total of 140 partners around the world organized a plethora of scientific and outreach activities. The MPE outreach activities included formal launches of the year, public lectures (including the international Simons Public Lecture Series), special issues of magazines, museum exhibitions, events for teachers, and a Math Awareness Month related to sustainability. Countries and partners contributed resources and new educational material and found creative ways to give a second life to older material. For example, the American Mathematical Society's "Math Moments" (now published twice a year in *Notices*) and the Society of Industrial and Applied Mathematics' "Nuggets" issued special pages to illustrate highlights related to MPE. Finally, several blogs were introduced around the world, including two daily blogs—one in English, one in French—that were both later published as books.

Key to the success of the MPE program was the selection of an inspiring theme of interest to scientists, schools, journalists, and the public alike. The scope of the initiative allowed getting the patronage of UNESCO and the endorsement of the International Council of Science, the International Mathematical Union, and the International Council of Industrial and Applied Mathematics. Another important ingredient of success was the delocalized structure. The MPE coordinator, Christiane Rousseau, from the Centre de Recherches Mathématiques in Montreal, Quebec, Canada, was assisted by several international committees, and the website migrated to a content management system where partners could post their events themselves.

**IMAGINARY.** Based at the Mathematics Institute at Oberwolfach, Germany, IMAGINARY is probably the most remarkable example of an international platform for open and interactive mathematics. It features a variety of content that can be used at home, in schools, at exhibitions, or in museums. The platform hosts picture galleries,

hands-on exhibits (such as sculptures, puzzles, games, and papercrafts) and films on many mathematical topics for teachers, students, and the public. It includes a variety of visually attractive and highly interactive software modules to explore mathematics in a variety of contexts, from the melting of alpine glaciers to the vibration of a bridge in response to an earthquake. These open-source exhibitions are cheap and readily accessible online. The free software to create algebraic surfaces is used to prepare many exhibits around the world, triggering competitions for the nicest algebraic surfaces. The IMAGINARY platform hosted the website for the international Math for Planet Earth competition, and it is currently hosting the international Open Source MPE Exhibition.

### Shared Challenges and Suggested Solutions

The lack of appreciation for mathematics and outreach in society and in our universities makes it hard to secure adequate funding for outreach activities. The relatively small number of professional mathematicians actively involved in outreach increases the burden. Faculty involved in such activities need to be allotted more support and credit.

A further difficulty lies in evaluating the effectiveness of outreach in its various guises. A simple survey after the activity may reveal whether the initiative was a success, but the rarely measured long-term impacts remain difficult to evaluate or quantify. Hence, such long-term impact studies of outreach activities should be both undertaken and shared, and the results used in funding applications or in dealings with policymakers.

Perhaps the most important theme in the workshop was the growing need to address these challenges further by sharing resources and ideas across international boundaries, including those that separate prosperous economies from developing ones. It was also stressed that there is great value in creating online resources, blogs, and newsletters to support communication among those involved in all of these outreach activities.

The community should also work together to encourage more people to do outreach, providing materials, training, and mentoring. Formal training on how to deal with the media would be valuable, especially for mathematicians leading wide outreach initiatives aimed at the general public, the media, or at policymakers.

Students should be considered as partners in the outreach mission. Partially during their studies and certainly after getting their degrees, it is natural for students to take an active part in the creation and dissemination of knowledge. Students can act as multipliers of the faculty's outreach efforts. In addition, students are a great resource for recruiting new people into outreach, since they are naturally perceived as role models by younger audiences. In fact, students often represent more gender, social, and ethnic diversity than faculty do. Training students in outreach is beneficial for instilling confidence and for sharing knowledge with nonmathematicians. Globally, support from departments and individual professors is needed to

help students become more involved with outreach so that they can show and develop their passion for mathematics.

### Deepening Connections and Moving Forward— Mathematics Outreach International (MOI)

Sharing a desire to continue efforts started at the workshop, participants decided to launch a new initiative: Mathematics Outreach International (MOI). MOI will support the expansion and enrichment of outreach activities worldwide, especially those aimed at developing countries and traditionally underrepresented groups. MOI will get advice from an international advisory board made up of prominent outreach leaders; launch a website containing resources and links to organizations, groups, and individuals coordinating national and international outreach activities; and contact the International Mathematical Union to explore the possibility of becoming an IMU committee. In addition, MOI will organize workshops and conferences and will propose them as satellite activities of international meetings of mathematical associations. MOI may also undertake other activities, such as the administration of an International Mathematics Outreach blog, a newsletter, or soliciting guidance from its advisory board on how to encourage policymakers to increase resources for mathematical outreach.

To ensure that things get started with a strong foundation, an initial MOI committee has been formed with members Martin Andler (France), Chris Budd (United Kingdom), Jean-Marie De Koninck (Canada), Janine McIntosh (Australia), and Diana White (United States). Eventually, it is hoped that a committee will be constituted on a more formal footing, actively involving the input and strong involvement of international and national mathematical associa-

tions, international mathematical research institutes, and the mathematical community at large.

The BIRS International Math Outreach Workshop provided a unique opportunity for a diverse group of outreach experts to come together to share ideas, network, and make plans for more collective efforts in the future. The participants encourage the broader mathematical community to view mathematical outreach as an essential part of its contribution to society and to consider getting involved and becoming more aware of ongoing efforts. They also solicit those in leadership positions to consider how mathematical outreach fits into their unit, as well as how they can promote mathematical outreach more broadly.

### Credits

Photo of the International Math Outreach Workshop participants courtesy of the Banff International Research Station.

Photo of the 2013 PIMS Summer Math Camp courtesy of the Pacific Institute for the Mathematical Sciences (PIMS).

Photo of the 2014 seminar courtesy of Jean-Marie De Koninck.

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