

## **COLLABORATIVE MATHEMATICS COMMUNICATION – EXPERIENCES AND EXAMPLES**

Andreas Daniel Matt, Mathematisches Forschungsinstitut Oberwolfach

Bianca Violet, Mathematisches Forschungsinstitut Oberwolfach

*In this paper we discuss experiences with a collaborative and participative approach of communicating mathematics to a broad audience. We give a list of recommendations and ideas, how the public itself can be involved in creating mathematics exhibits and can become an integral part of outreach activities. The ideas are accompanied by sample activities we carried out within “IMAGINARY – open mathematics”, a project by the Mathematisches Forschungsinstitut Oberwolfach supported by the Klaus Tschira Stiftung.*

### **EXPERIENCES**

In this section we list key experiences and general strategies, which we think are essential to enable collaborative mathematics communication. They are drawn from seven years of experience carrying out collaborative mathematics communication on an international level.

#### **Open Mindset and Open Design**

Conducting a collaborative outreach project differs from implementing a standard project in a very important way: its hierarchy. The initiators of the collaborative project have to give up power of control. A more horizontal hierarchy needs to be established and the “experts vs. public” demarcation line vanishes. You, as initiator, will become a participant of the project and have to be open for new ideas and input from others. All participants will share the process of their project activities. It is more difficult to foresee the outcome. The idea of a collaborative project is to jointly create something new. This could be a whole mathematics exhibition, created with many participants, including members of the general public. Collaborative projects usually start with calls to the public to get involved. Virtual co-working tools can then help to successfully implement the project.

#### **Communication and Tools**

Communication is fundamental to the involvement of the public, for example by using contacts from your professional network or by making new connections to a relevant community. Usually the first point of contact to reach out to the public is by means of email and social media, but also through the use of personal meetings and classical formats as flyers or posters. To integrate new collaborators, we schedule phone or video conferences to get to know each other and exchange ideas. All participants have to clearly know, what they are expected to contribute and who their main contact persons are. For all our projects, a fast communication and a friendly non-formal tone proved to be important. We use several collaborative tools for project management and for brainstorming new concepts online. These tools are essential for information flow and guarantee a successful finalization of projects with strict deadlines.

## **Creative Interaction**

A keyword in modern communication is “user-generated content”. In order to motivate users to add new content or ideas, we design and offer tools for creative interaction. The idea of creative interaction is simply, that users - for example at a mathematics exhibit - can create something new, which can then surprise the authors of the tool or in our example of the exhibit. In other words: as a user you are not limited to a finite (often small) number of given options. Such tools motivate the public. They are designed to inspire and to create personal content and do not only repeat given patterns. It gives users the power to be creators, inventors, and mathematicians themselves. As a next step the user creations can be showcased, for example, at the exhibition they were created.

## **Open Source and Open Access**

To participate, the members of a collaborative project need access to the data and content of the project. It is crucial to have an organizational structure in place that will allow a fluid integration of reused and novel contributions. We use open source and open access licenses for all our mathematics communication content. The source code of software is hosted on online repositories with free access, all source files for texts, posters, press releases, budgets or funding proposals are shared. In this way, participants can make further use of the available content and adapt it to their needs. Ideally, new extensions are then also shared under the same open licenses. This leads to a growing archive of digital data, reusable to communicate mathematics. Sharing all data makes the project transparent, and also adds to the motivation of participants to be involved.

## **New Collaborative Formats**

We make use of new formats of collaborative outreach activities, with some derived from classical formats as exhibitions, films, or museums. We organize calls for participation or competitions to include the public and encourage their participation. In the past we have organized collaborative workshops, where the public chooses topics and works jointly on a set of targets with a concrete output goal. We offer a so-called “open source exhibition”, where we collaborate with participants to locally organize exhibitions, in particular but not exclusively to help to also include new content. The buzzword for these new formats often is “crowd”, such as crowd funding or crowd science.

## **EXAMPLES**

The project “IMAGINARY - open mathematics” started in 2008 as an interactive travelling exhibition that presents visualizations, interactive installations, virtual worlds, 3D-objects and their mathematical background in an attractive and understandable way. Over the last years it has developed into an open source organization including a platform and a network for interactive and participative mathematics communication [Greuel, Matt, Mey, 2014]. In the following, we give specific examples of our experiences with collaborative and participative projects within IMAGINARY. We try to connect the examples to our experiences mentioned above.



Figure 1: SURFER station in an IMAGINARY exhibition in Argentina, 2012.

## **The Software SURFER**

SURFER is an interactive software to visualize algebraic surfaces. It is intuitive and has been developed for a broad audience [Garousi, 2011]. You can enter simple equations whose solutions are surfaces in space, resulting in beautiful images, see Figure 1. This interaction fascinates and casually transmits geometric intuition and mathematical understanding.

In exhibitions, the users can print out their own creations on site including the formula, which can either become part of the exhibition itself or can be taken home (or on some other adventure), see Figure 2. We have organized exhibitions, which consisted entirely of user generated SURFER images. This way, the exhibition itself is built from scratch step by step by the visitors.



Figure 2: Left: Visitor-created exhibition at the Phaeno in Wolfsburg, 2013. Right: SURFER users at the IMAGINARY exhibition at the Ideenpark in Stuttgart, 2008.

The SURFER software is open source and can be downloaded for free. As a result artists and software developers started to use and change the software. New extensions and different approaches emerged, for example adding new input devices, using SURFER animations as live visuals for events, the random generation of surfaces or creating algebraic surfaces out of words by linking letters with formulas. SURFER is an example of a creative interaction tool. It is widely used by the general public to communicate algebraic geometry through pictures and animations.

## **Math Art Competitions**

The program SURFER as well as other programs such as Morenaments [Gagern, 2008] were used to inspire users to create their own art and to collect user-generated galleries and animations through online competitions [Pöppe, 2008]. Some have attracted several thousand users. Different competitions were run in many countries – Slovenia, Uruguay, Portugal, Germany, Taiwan, Israel and Croatia. Some challenged the participants to create new images on a specific subject such as ocean biodiversity. Schools organized workshops and the resulting works were submitted to the online competitions. All submissions are visible in an online gallery during and after the competition. The authors are acknowledged and each formula is made publically available. Most competitions will have prizes for at least the top submission judged by a jury, but occasionally prizes are awarded in categories, for instance according to the age of the participants, and sometime as a particular reward, winning images become part of new exhibitions. This is an example of a collaborative format, where through a competition participants share creations and jointly

communicate mathematics. There are plans to develop an online tool as part of the IMAGINARY platform offering users an easy setup for competitions in any language and many possible adaptations.

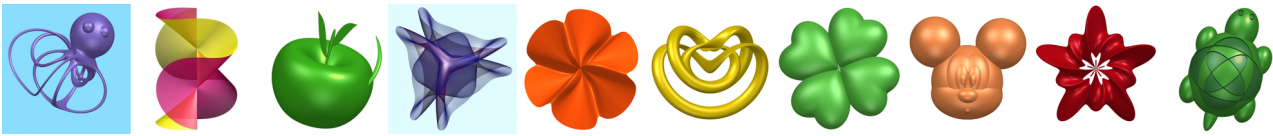


Figure 3: Submission examples from international SURFER competitions.

### Mathematics of Planet Earth

Mathematics of Planet Earth (MPE) is an initiative of mathematical sciences organizations around the world designed to showcase the ways in which mathematics can be useful in tackling our world's problems. The MPE Open Source Exhibition ([www.imaginary.org/mpe](http://www.imaginary.org/mpe)) was entirely created by the community through an international competition [Behrends, Rodrigues, 2012]. The winning modules are now part of this international virtual exhibition, launched in March 2013 at the UNESCO Headquarters in Paris. The modules are reproducible and used by users around the world from science museums to schools. The exhibition has a virtual part, as well as several physical parts. Copies of the physical parts can be recreated to travel around the world, and the virtual modules are available on the basis of creative commons licenses on the IMAGINARY platform. This project is an example of a collaborative exhibition, which was launched and matured by the community.

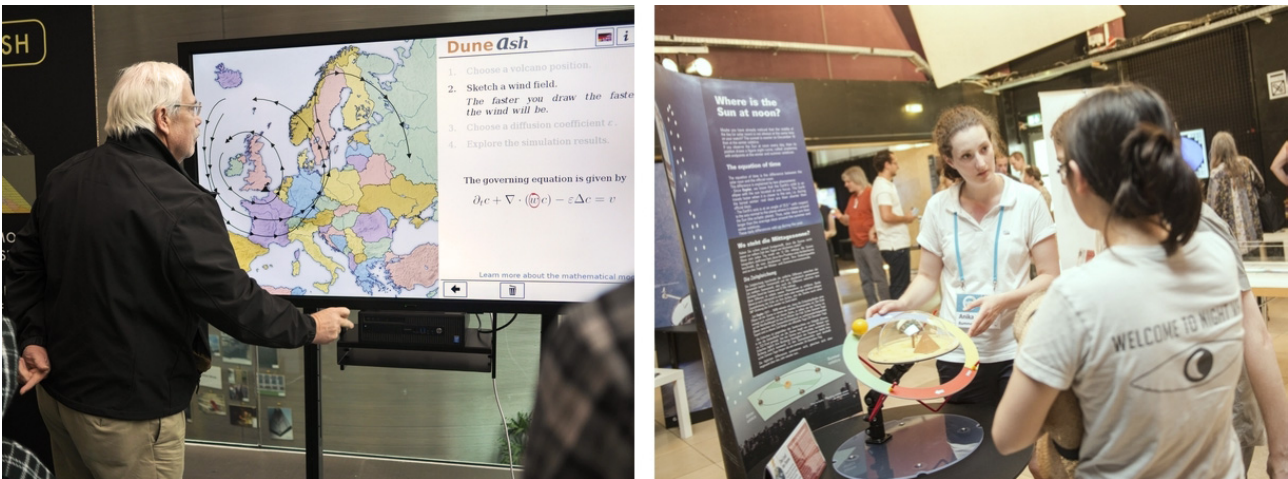


Figure 4: MPE exhibitions in 2015. Left: London. Right: Heidelberg (© Klaus Tschira Stiftung).

The Next Einstein Forum Global Gathering 2016 in Dakar, Senegal, hosted the launch of a new international competition for MPE exhibition modules. This second international competition, jointly organized by IMAGINARY, UNESCO International Basic Sciences Programme (IBSP), the International Mathematical Union (IMU) and the International Commission on Mathematical Instruction (ICMI), will enrich the exhibition with new modules, aiming to address challenges in Africa and other regions of the world. For each submitted exhibit an open license must be chosen. The deadline for submissions is in June 2017.

### The Taskbook by Vladimir Arnold

The taskbook for school students “Problems for children from 5 to 15” by renowned Russian mathematician Prof. Vladimir Igorevich Arnold consists of 77 problems for the development of a thinking culture, either selected or composed by the author ([www.imaginary.org/arnoldbook](http://www.imaginary.org/arnoldbook)). We were offered the Russian version of this booklet and prepared an English translation. After releasing the sources (LaTeX, images) we invited the community to translate and work with its content. After just two years, the community translated the booklet into German, Spanish, Italian, Vietnamese and Turkish. A Portuguese translation is currently in progress, which will also include solutions. There are also plans to add didactic material for teachers. This is an example of allowing the community to get involved in a publication, which continues to develop. It shows the advantage of a good online repository, where source files are hosted and translations can be done without asking for permission.

### Open Platform for Mathematics Communication

The aim of the platform “IMAGINARY - open mathematics” ([www.imaginary.org](http://www.imaginary.org)) is to provide a space for the presentation and development of math exhibitions. The platform offers an opportunity for everyone interested to contribute with their own material and serves as a hub for exchange of ideas in the field of mathematics communication. The target group of the platform also includes museums, universities and schools. All contents of the platform are made available to a broad audience under a free license and can thus be reproduced and used for individual exhibitions and events. The main contents are its interactive programs and its picture galleries, but also hands-on exhibits, texts or films are shared. The core idea is that exhibits are created within the community and exhibitions are organized independently. Users can add their events to the IMAGINARY calendar, see Figure 5, invite others and share their experiences. The platform is a tool to enable collaborative organization of mathematics exhibitions. This concept and the platform grew from the beginning of IMAGINARY in 2008 and the community has organized over 150 exhibitions in 45 countries and 23 languages using the online resources.

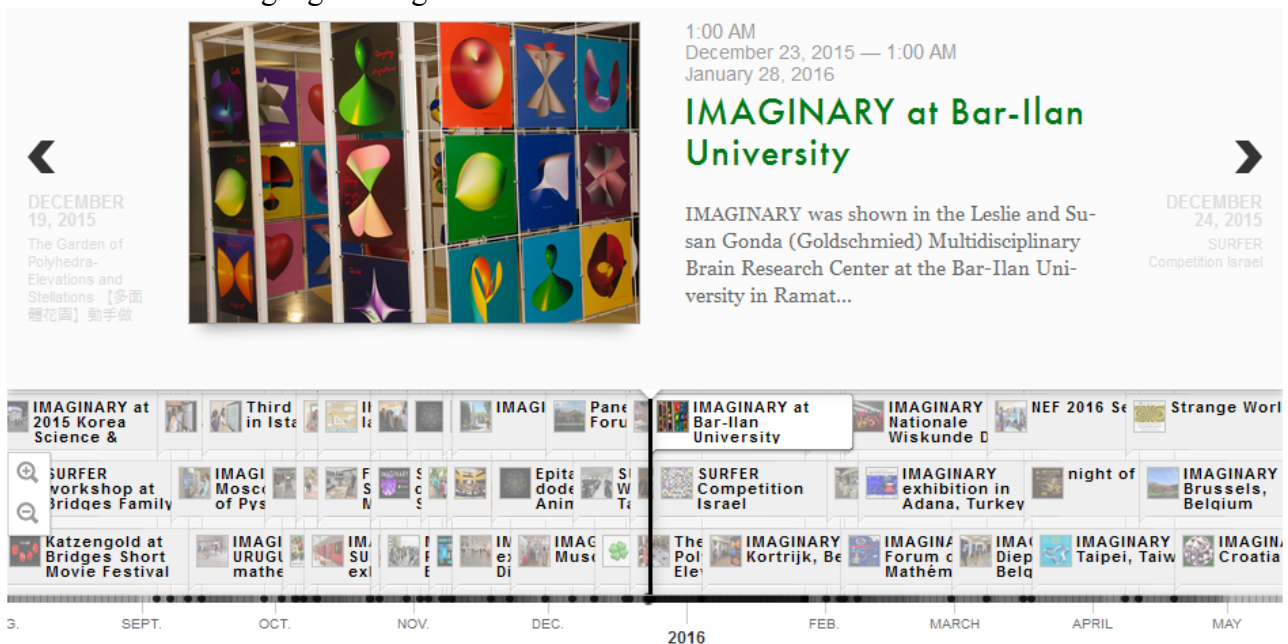


Figure 5: Excerpt of the IMAGINARY calendar at the IMAGINARY platform.

## **Snapshots of Modern Mathematics from Oberwolfach**

Yet another aspects of the collaborative environment of IMAGINARY are the so-called “Snapshots of modern mathematics from Oberwolfach”. These snapshots are short, easy to understand articles on current topics of mathematical research. They explain mathematical problems and ideas in an accessible and understandable way, and provide exciting insights into research topics of the mathematical community for everyone who is interested in modern mathematics. Each snapshot is written by an expert in that field of mathematics: At the Mathematisches Forschungsinstitut Oberwolfach, every week 50 to 60 experts from all over the world work together on current challenges in the field of Mathematics. They introduce new results, discuss different approaches and develop new ideas. After each symposium, the institute asks selected participants to explain one aspect of their research in a comprehensible language to a general audience on a few pages. A team of young mathematicians edits the articles in close collaboration with the authors and assists them in communicating complicated matters to a broad audience. Together they prepare an edited version for publication under an open license. The collaborative project of the research mathematicians is designed to promote the understanding and appreciation of modern mathematics and mathematical research in the general public worldwide.

## **Mathemafrika**

Mathemafrika is a multilingual, multiblogger platform about mathematics within or with relevance to Africa ([www.mathemafrika.org](http://www.mathemafrika.org)). Everyone is invited to participate; to read, write, translate and share articles. The idea of the project as well as a first outline, planning phase and implementation of the platform originated in a collaborative mathematics communication workshop conducted in November 2014 in South Africa [AIMS, 2014], see Figure 6. Participants jointly planned future scientific and educational public engagement/outreach activities. From the beginning, the community was involved in creating and shaping the platform and now in further developing it.



Figure 6: AIMS-IMAGINARY exhibition and workshop in South Africa, 2014.

## **Mathematikon – A Mathematical Shopping Center**

In January 2016 IMAGINARY took on the challenge to create and design modern mathematical content to be permanently integrated into a shopping center in Heidelberg [Violet, Matt, 2016]. The aim of the mathematical installations was to encourage people to think about mathematics during everyday errands, to amaze and to activate thought-provoking impulses. Together with mathematicians and artists from all over the world – precisely from 14 countries – we created a unique composition of art gallery, shopping center and science center. The ideas and contents for the Mathematikon are all open licensed. The installations include twelve big format images with intelligible descriptions providing insights into different fields of mathematics. For the supermarket

and the drugstore of the shopping center, we created four different mathematical designs for the conveyor belts; so waiting at the cashiers can be fun and entertaining.



Figure 7: Examples of the conveyor belts at the cashiers in the Mathematikon, 2016.

The highlight of the mathematical content in terms of popularity as well as state of the art technology is the 84 inch multi touch screen station. It is mounted vertically in the central hall of the shopping mall. Altogether 10 interactive math games based on the Cinderella applets are offered, two of them can be explored at the same time; at a height for adults and children.

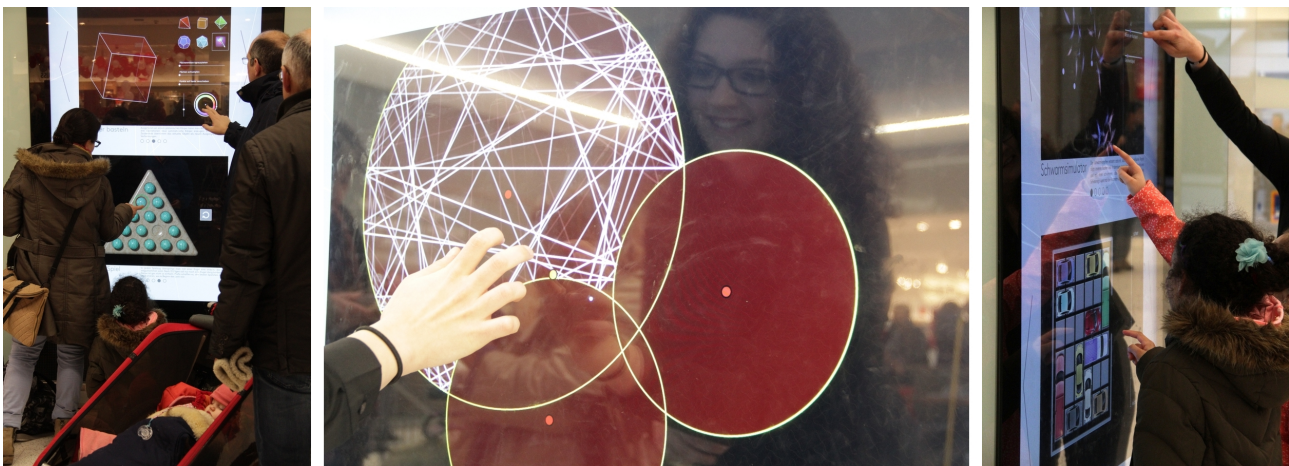


Figure 8: Multi touch screen station in the Mathematikon, 2016.

Integrated in the bathroom mirrors are screens, which display 25 short riddles of varying difficulty covering different areas of mathematics. The showcase area of a yet to be rented shop was used to temporarily display a combination of math and art, including big format 2D prints, 3D printed models as well as hanging paper sculptures. This project was implemented at a very short timescale of 6 weeks. This was only possible through a collaborative approach with many participants. A big motivation for all collaborators was the uniqueness of the project and the dynamics of being part of a professional team.

### **IMAGINARY Conference 2016**

The IMAGINARY Conference on Open and Collaborative Communication of Mathematical Research 2016 (IC16) is an interdisciplinary gathering of mathematicians, communicators and interested professionals who wish to discuss and work together on current issues of communication and knowledge transfer in mathematics. In contrast to a classical conference, IC16 will take a participative and collaborative approach in order to advance new ideas, bring forward concrete results and help shape the future of mathematics communication. The program consists of talks by

community members as well as workshops, which are run in parallel. Participants work in small groups of up to 15 on specific projects, which can be achieved in the given time frame of three afternoons. Results will be shown in a public presentation at the end of the conference and are planned to be offered under an open license afterwards. Each participant is co-author of the output of the workshop he or she took part in.



Figure 9: Images from the planned workshops and workshop conductors at the IC16 conference.

## INVITATION AND FUTURE

To conclude our paper, we would like to invite you to be part of our mathematics communication project and network ([www.imaginary.org/network](http://www.imaginary.org/network)) [Ramos, 2014]. There are many extraordinary projects around the world that bring the beauty of mathematics closer to the general public, and each one of these has very valuable experiences worthwhile to be shared. Math and science museums, traveling exhibitions, individuals devoted to the dispersion of mathematics - all these agents are not competitors, but rather provide outreach services that can benefit from an active exchange of experiences, opinions, and strategies. We would be happy to work on joint ideas and to find out more about your experiences in collaborative mathematics communication. It would be of big interest to further investigate mechanisms of how to establish collaboration in general, with a special focus on mathematics outreach projects.

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