



Einstein Center for Mathematics Berlin

Professor Ralf Kornhuber, EMath Chair

Handwritten text on the red sphere:

$$ax^2 + bx + c = 0$$

(b) into an irreducible form $x^2 + px + q = 0$. To the form $x^2 + px + q = 0$ we add $\frac{p^2}{4}$ to both sides and get $x^2 + px + \frac{p^2}{4} + q - \frac{p^2}{4} = \frac{p^2}{4}$ or $(x + \frac{p}{2})^2 = \frac{p^2}{4} - q + \frac{p^2}{4} = \frac{p^2 - 4q + p^2}{4} = \frac{p^2 - 4q + p^2}{4} = \frac{2p^2 - 4q}{4} = \frac{p^2 - 2q}{2}$

Binomial expansion of $(x + \frac{p}{2})^2$:

$$(x + \frac{p}{2})^2 = x^2 + px + \frac{p^2}{4}$$

Setting $(x + \frac{p}{2})^2 = \frac{p^2 - 2q}{2}$ and substituting it into the original equation:

$$x^2 + px + \frac{p^2}{4} + Q(y+z) + R = 0$$

$$x^2 + 3yz + 3yz + 2z^2 + Q(y+z) + R = 0$$

$$3yz + Q = 0$$

Pascal's triangle (10 rows):

1									
10	34	21	1						
1	1	9	1						

Pascal's triangle (10 rows) with red diagonal lines:

1									
10	34	21	1						
1	1	9	1						

Pascal's triangle (10 rows) with red diagonal lines and numbers:

1									
10	34	21	1						
1	1	9	1						

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Education, research and industrial application of mathematics are extremely healthy in Berlin, thanks in no small part to the efforts of ECMath and its constituent and collaborative organisations, as **Professor Ralf Kornhuber**, ECMath Chair, expounds

What needs was the Einstein Center for Mathematics Berlin (ECMath) intended to fulfil when it was founded in 2014?

ECMath is the first Einstein Center of the Einstein Foundation Berlin. It is also supported by the three Berlin universities: Freie Universität (FU), Humboldt-Universität (HU) and Technische Universität (TU), and by two Berlin research institutes, the Zuse Institute and Weierstrass Institute.

Since funding by the German Research Foundation (DFG) terminated in 2014, ECMath provides a continuation of application-orientated basic research and, beyond that, establishes a network of mathematical excellence initiatives and projects in Berlin.

How do the research endeavours of ECMath build upon those of its constituent organisations?

ECMath is the common platform for excellent mathematics in Berlin. One of its members is MATHEON and others include the Berlin Mathematical School (BMS), German Center for Teacher Education in Mathematics (DZLM), Research Campus Modal and several Collaborative Research Centers (CRCs) or Transregional Research Centers (TRs). Thus, ECMath is connecting mathematical research and education, ranging from foundations to industrial applications in one big unit. This is a sound basis for further initiatives, like the organisation of the 7th European Congress of Mathematics in 2015.

Could you select and discuss one project from each of ECMath's four Innovation Areas (IAs) that you feel is particularly impactful?

In light of the quality of all of these projects, which have been selected in a highly competitive process, the answer must be a matter of personal taste. In the IA 'Clinical Research and Health Care', I like a project called 'Sparse compressed sensing based classifiers for -omics mass-data'. It combines deep theoretical insight from approximation theory with state-

of-the-art bioinformatics techniques to provide better understanding of pathogenic mechanisms and new diagnosis tools for life-threatening diseases.

The project 'Design and operation of infrastructure networks under uncertainty' is one of the highlights of the IA 'Metropolitan Infrastructures', because

it provides structural understanding and numerical algorithms on how to balance the cost of data exploration on one hand with actual benefit in terms of quality of optimal design, operation and maintenance of metropolitan infrastructures on the other. These calculations involve factors such as presence of uncertain processing durations, transit times, cost, market prices, customer demands, energy consumption, etc.

While the preceding two projects will have short-term practical impact, the benefits from the next two projects will be felt on a medium- to long-term scale. The project 'Mathematical modeling, analysis, and optimization of strained germanium-microbridges' in the IA 'Optical Technologies' concentrates on the optimisation of optoelectronic contact layers to improve the processing performance of optoelectronic devices beyond that using electricity and copper contacts.

Finally, the fourth project 'Plasmonic concepts for solar fuel generation' in the IA 'Sustainable Energies' could almost be described as visionary. With scientists from the Junior Research Group 'Artificial Photosynthesis/Scientific Computing' working with cooperation partners from the Helmholtz-Zentrum für Materialien und Energie Berlin, the initiative aims at contributing to the direct production of hydrogen from sunlight through photoelectrolysis, which in turn can be used to produce electricity overnight, when the Sun does not shine.

Can you explain what the concept of 'Mathematics as a Whole' is, and why it is central to ECMath's education priority?

The power of mathematics is abstraction. Just the same as everybody else, mathematicians cannot imagine what n -dimensional spaces or an angle between two functions look like, but abstraction allows us to operate with such concepts according to clear rules. This structural perspective often allows apparently complicated circumstances to become clear, and the resulting joy of understanding can be shared by schoolchildren, students and professors alike. This idea of 'Mathematics



as a Whole' is our common basis for the education of school teachers and students as carried out by DZLM and BMS, and forms the foundation of our scientific research in the other ECMath initiatives.

In your view, why is there a continuing loss of women from mathematics, particularly at the higher levels of research and teaching? Is ECMath active in addressing this deficit?

This is a difficult question that is tackled by various members of ECMath in a number of different ways. In particular, BMS has implemented several strategies to tackle this problem, such as role model events and a special mentoring system to support women in the early stages of their career. As PhD students in other ECMath initiatives and projects are usually members of BMS as well, these means essentially cover everyone involved in the Center.

For later stages of academic careers, ECMath cooperates closely with ProFiL, a well-established joint programme of FU, TU and HU that is supporting female postdocs on their way to a permanent professorship.

Why was Modal AG set up and what assistance does it offer researchers keen to commercialise their innovations?

Modal AG was founded by the Research Campus Modal in cooperation with ECMath as an interface between application-orientated research, in particular in MATHEON, and industrial application. Modal AG's service concentrates on legal issues such as warranty or intellectual property and software aspects such as long-term maintenance. In this way, Modal AG helps to provide a professional framework for the transfer of new ideas into industrial practice.

Could you offer one example of a project that has been developed into a spin-off company through the assistance of ECMath?

In its pre-phase in 2013 ECMath launched one-year startup projects in order to bridge the gap between scientific research and possible industrial applications. A project on 'Proteome-based early-stage lung cancer diagnostics' provided a proof of concept and developed a software prototype for a lung cancer test by means of analysing proteome-based mass spectrometry data. The corresponding mathematical framework was and is a subject of basic research in MATHEON, software development was carried out in cooperation with the SAP Innovation Center, and clinical validation is based on a lung cancer dataset provided by Helios Clinics, Berlin.

Early diagnosis of the disease and early relapse monitoring are currently the best available options to improve patient survival. A spin-off company is being founded for further development, maintenance and commercial distribution of this new diagnostics software and will be completed by the end of this year.

With a growing presence in Berlin's mathematical education, research and industry sectors, how do you improve links between these often siloed areas?

In Berlin's mathematics community, strong links between education (of teachers and students), research and industrial applications have been well-established since the early days of MATHEON. Its Application Area 'Education and Outreach' was and still is devoted to the communication of mathematics to teachers, students and the public. One of its most successful initiatives is the so-called 'Mathematischer Adventskalender', which sets a mathematical problem each day of December until Christmas that more than 10,000 schoolchildren try to solve each year.

A very unexpected effect of our efforts to communicate mathematics to others was the improvement in communication among ourselves. Over the last decade, this process led to an atmosphere of openness, respect and curiosity that has turned the diversity of education, research and industrial application from a problem into a pleasure.

What are ECMath's plans for the next few years? How would you like to see the links between education, research and industry in relation to mathematics evolve both in Germany and across Europe?

In the years to come, we plan to concentrate on strengthening and exploiting possible scientific collaborations among all the excellent mathematicians working in a variety of mathematical fields and initiatives in ECMath. First experiences with the newly introduced ECMath Salon, a kind of scientific talk show, and the ECMath Colloquium, which is intended to provide a crossover of different fields, are very promising.

We would also like to broaden our spectrum of cooperation partners beyond mathematics. Further to already well-established links with natural sciences, engineering and industry, we would like to enhance cooperation with social sciences and the humanities.

And finally, we are keen to develop close ties with similar initiatives to MATHEON, BMS and ECMath in other countries. We recently created a post to act as a representative for European joint initiatives in order to set, support and cooperate with similar organisations and institutions on the European level and beyond.