

# Report on the Study

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## 1 Aim and Scope of the Study

The Study on “Educational Interfaces between Mathematics and Industry (EIMI-Study)” was organized jointly by the International Commission on Mathematical Instruction (ICMI) and the International Council for Industrial and Applied Mathematics (ICIAM). Both institutions were interested in the topic of the study, which was stimulated by a recent OECD Report. ICMI and ICIAM were also keen on cooperating to better understand the connections between the teaching and learning of mathematics on all levels as well as the role of mathematics in industry. As such, it was the 20th ICMI-study and the second developed in cooperation with another association. As usual with ICMI-studies, the EIMI-study wants to offer ideas and suggestions on how education and training can contribute to enhancing both individual and societal developments—in this case also building on the experience and competence of mathematicians from industry.

Following the framework of ICMI-studies, the EIMI-study was begun by appointing an International Program Committee (IPC) with two co-chairs (Alain Damlamian appointed by ICIAM and Rudolf Sträßer from ICMI) and members proposed by both organizations: Helmer Aslaksen (Singapore), Gail Fitzsimons (Australia), José Gambi (Spain), Solomon Garfunkel (USA), Alejandro Jofré (Chile), Gabriele Kaiser (Germany), Henk van der Kooij (Netherlands), Li Ta-t sien

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(China), Brigitte Lutz-Westphal (Germany), Taketomo Mitsui (Japan), Nilima Nigam (Canada), José Francisco Rodrigues (Portugal, host country), Fadil Santosa (USA), Bernard Hodgson (ex-officio, ICMI), and Rolf Jeltsch (ex-officio, ICIAM).

As can be read in the Discussion Document, the EIMI-Study starts from two assumptions, namely:

There are intimate connections between innovation, science, mathematics, and the production and distribution of goods and services in society. In short: there are intimate connections between mathematics and industry;

In view of these connections, there is a need for a fundamental analysis and reflection on strategies for the education and training of students and maybe the development of new ones.

Historically, there have been productive interactions between mathematics and industry in generating and solving problems associated with the economic and social development of humankind. In a modern, technological world, mathematics is said to be used almost everywhere. However, these uses are not generally visible except to specialists. Even people using mathematics in their workplaces may not recognize its presence. There have been many studies of the mathematics used in the workplace—ranging from descriptive lists of traditional school-based topics to sociological studies of workplace activities set in context. There have been many collections of applications of problem solving and modeling based on or informed by practical industrial problems, especially at higher levels of mathematics, in fields such as the natural and physical sciences, engineering, and finance.

Internationally, there are frequent articles and debates in the popular media citing employer dissatisfaction with the perceived quality of mathematics education. Graduates from schools, vocational colleges, and universities often appear unable to draw upon and use mathematics in work situations as opposed to classroom or examination contexts. At all educational levels, students typically have been taught the tools of mathematics with little or no mention of authentic real world applications, and with little or no contact with what is done in the workplace (be it the classical engineering situations or other more recent activities like biotechnology, biomedicine, the financial, insurance and risk sectors, or consulting engineering companies). Nowadays, highly complex problems need to be solved and, hence, some training to solve such problems—in particular, real life problems—is necessary. Increasingly, powerful computers make it possible to treat such complex problems and this is achieved not only using off-the-shelf software but with innovation, often mathematical innovation requiring insight and analysis.

In order to better understand these phenomena, the Study starts from a broad definition of Industry (from the Organisation for Economic Co-operation and Development) “... broadly interpreted as any activity of economic or social value, including the service industry, regardless of whether it is in the public or private sector” (OECD 2008, p. 4). The term “industry” obviously refers to a diverse range of activities, producing goods, and services. Under constraints such as time and money, these activities generally attempt to optimize limited -sometimes scarce- resources, both material and intellectual. The overarching goal is to

maximize benefits for certain groups of people while, ideally, minimizing harm to other groups and the natural environment. “Mathematics (or the mathematical sciences, here the two terms are used interchangeably) comprises any activity in the mathematical sciences, including mathematical statistics” (OECD 2008, p. 4). Workers at all levels utilize mathematical ideas and techniques, consciously or unconsciously, in the process of achieving the desired workplace outcome. In other words, mathematics is just one part of a repertoire of tools and strategies of a practical nature. However, as a major factor in decision-making and communication processes, it is crucial that mathematics be used appropriately, accurately and with confidence. For this Study, we start from the assumption that professional mathematicians are located in academia, in industry, sometimes in both. The discourse of mathematics in all its various specializations involves certain ways of thinking and acting. Traditionally, mathematicians consider axioms and definitions and make logical deductions. In mathematical modeling, one formulates problems in mathematical terms. However, the mathematical solution needs to take into account the industrial context. This Study examines the implications for education at the intersection of two communities of practice industrialists and mathematicians—or industry and mathematics. We emphasize that there should be a balance between the perceived needs of industry for relevant mathematics education and the needs of learners for lifelong and broad education in a globalized environment. In other words, learners should be equipped for flexibility in an ever-changing work and life environment, globally and locally.

Intended beneficiaries of this study include, among others:

students enrolled in formal education systems across all sectors, including vocational, secondary, tertiary, and even primary,  
preservice teachers (teacher students) and practicing teachers involved in continuing education or professional development programs,  
teacher educators for the above categories,  
learners undertaking workplace education, from low-skilled workers through to management (and their workplace teachers/trainers),  
industry decision makers,  
mathematicians working in industry (or having an interest in the applications of their field).  
and eventually, all policy makers.

The aims of the Study are:

to broaden the public awareness of the integral role that mathematics plays in society with respect to low and high-technology industries,  
to broaden the awareness of industry with respect to what mathematics can and cannot realistically achieve under current circumstances,  
to broaden the awareness of industry with respect to what school and university graduates can and cannot do realistically in terms of mathematics,  
to broaden the awareness of mathematics teachers and educators with regard to industrial practices and needs with respect to education,

to enhance the appropriate usage of mathematics in society and industry (e.g., by presenting examples of good practice),  
 to attract and retain more students, encouraging them to continue their mathematical studies at all levels of education through meaningful and relevant contextualized examples,  
 and to improve mathematics curricula at all levels of education.

In the views of the International Program Committee, there is a need for this Study in order.

to create new and innovative educational practices and support existing good practices,  
 to ensure that, when used as an employment selection tool, mathematics is used appropriately,  
 to develop in learners the mathematical reasoning and logical thinking needed in industry,  
 and to enhance the dialog and understanding between the communities of mathematicians, workers and industry decision makers, politicians, and educators.

## 2 The Discussion Document

In a meeting in Óbidos, Portugal, hosted by the Centro Internacional de Matemática in October 2008, the International Program Committee prepared the Discussion Document (DD) for the EIMI-Study. After presenting the basic definitions and rationale for the Study as described above, this document consists of eight chapters which detail the situation in the field and raise questions to be considered in order to meet the expectations for the study. Below, we give the titles of the chapters of the Discussion Document.

- The role of mathematics—visibility and black boxes.
- Examples of use of technology and mathematics.
- Communication and collaboration.
- Teaching and learning of industrial mathematics—making industrial mathematics more visible.
- Using technology and learning with technology: modeling and simulation.
- Teaching and learning for communication and collaboration.
- Curriculum and syllabus issues.
- Teacher training.

In addition, the DD asks for good practices and lessons to be learned as well as comments and suggestions for research and documentation.

The DD was distributed in the widest way possible—including the publication in the official ICMI-journal “L’enseignement mathématique” and “ZDM The International Journal on Mathematics Education” (see the text in this volume or Damlamian and Sträßer 2009 or [http://eimi.glocos.org/?page\\_id=203](http://eimi.glocos.org/?page_id=203)). A website was created even before the Óbidos meeting (see <http://eimi.glocos.org/>).

### 3 The Contributions Offered

After the publication of the Discussion Document, the International Program Committee received 70 texts from all five continents to be considered for inclusion in the Study. Authors proposed their texts by the end of October 2009. These were evaluated in view of a possible invitation to the Study Conference. To this end, the IPC met in Paris in the beginning of November 2009. Beyond deciding on possible contributions to the Study Conference, the major challenge of this meeting was to find an efficient way to organize the conference and to structure the discussions. The IPC finally agreed to have six plenary talks during the conference, while the major work was to be done in six “Working Groups” with topics to be discussed during the Study Conference. Each Working Group would be given six hours for presentation of texts and discussion of their topic with an opportunity of presenting the results in a plenary session of the conference (for details see the section below).

After revisions, it was decided to gather 54 papers and the Discussion Document in a proceedings book to be published before the conference (planned for April 2010). The volume was made available early in April 2010 (see Araújo et al. 2010). The proceedings were offered to every participant of the Study Conference as a printed book. This collection of papers on “Educational Interfaces between Mathematics and Industry” can be freely downloaded from [http://www.cim.pt/files/proceedings\\_eimi\\_2010.pdf](http://www.cim.pt/files/proceedings_eimi_2010.pdf).

### 4 The Study Conference

The second major step of every ICMI-study is a Study Conference to bring together experts from all over the world and make them share ideas on the topic of the study at hand. The ICMI-ICIAM-study on “Educational Interfaces between Mathematics and Industry (EIMI-study)” exactly followed this road by asking for contributions and comments to the DD and then by inviting about one hundred people to the Study Conference. This conference was held in Portugal, as a tribute to the fact that its National Committee of Mathematicians made the original suggestion for this Study. It was organized by the Centro Internacional de Matemática (CIM) and scheduled to be held in Lisbon on April 19–23, 2010.

Colleagues from all over the world registered for the conference, but the ashes of the Icelandic volcano Eyjafjallajökull simply made it impossible to run the

conference in April 2010. At the planned beginning of the conference, there were no flights over most of Europe for several days, so the conference organizers had to cancel the conference—and soon decided to postpone it to October 11–15, 2010. In October 2010, the postponed conference took place at the University of Lisbon, with the participation of the majority but not all registered participants and discussed the 54 papers published in April in the Proceedings. These were grouped in order to link them with the six Working Groups of the conference, which were planned to act as the places of discussion and preparation of the Study Volume. The working Groups were entitled:

- WG 1: The mathematics-industry interface (mainly looking at [Sects.2](#) and [6](#) of the [Discussion Document](#)).
- WG 2: Technology issues (mainly looking at [Sects.3](#) and [6](#) of the [Discussion Document](#)).
- WG 3: Mathematics-Industry Communication (mainly looking at [Sects.4](#) and [11](#) of the [Discussion Document](#)).
- WG 4: Education in Schools (mainly looking at [Sects.5](#), [7](#), [8](#), and [9](#) of the [Discussion Document](#)).
- WG 5: University and academic technical/vocational education (mainly looking at [Sects.5](#), [7](#), [8](#), and [9](#) of the [Discussion Document](#)).
- WG 6: Education/training with industry participation (mainly looking at [Sect.6](#) and pertinent parts of [Sects.5](#), [7](#), [8](#), and [9](#)).

The Working Groups were bundled into two sets scheduled to meet in the first half and second half of the Study Conference. Consequently, each participant could participate in one of WGs 1, 3, or 6 and later during the week in one of WGs 2, 4, or 5. Each Working Group had 330 min working time and the respective reports were presented during a plenary session.

In addition to the conference opening and closing session, the following six plenary talks were given with the purpose to present expert views on mathematics in industry and on workplace related mathematics in educational settings (i.e., workplace related Didactics of mathematics):

- Thomas A. Grandine (Applied Mathematics, The Boeing Company, Seattle, USA):  
The use of Mathematics in Industry.
- Arvind Gupta (Director/CEO of MITACS, University of British Columbia, Canada): Industrial Mathematics in Academia (plenary presented by Nilima Nigam).
- Celia Hoyles (Institute of Education, University of London, UK): Research on Mathematics in the Workplace (plenary presentation held via Skype).
- Henk van der Kooij (The Freudenthal Institute, Utrecht University, The Netherlands): How to integrate work-related math in mathematics education?
- Helmut Neunzert (Fraunhofer ITWM, University of Kaiserslautern, Germany):  
Models for Industrial Problems: How to find and how to solve them — in industry and in education (plenary presentation held via Skype).

Masato Wakayama (Faculty of Mathematics, Kyushu University, Japan): A Trial for PhD Education and Research in Mathematics for Industrial Technology.

Papers in the proceedings which could not easily be linked to exactly one of the Working Groups were presented in paper presentation sessions (two or three presentations in parallel) (for detailed information see the program of the Study Conference at [http://eimi.glocos.org/?page\\_id=319](http://eimi.glocos.org/?page_id=319); there is also a list of the participants of the Study Conference at [http://eimi.glocos.org/?page\\_id=787](http://eimi.glocos.org/?page_id=787)).

## 5 Work After the Study Conference

With the purpose of contributing to this on-going study, to complement the Study Conference and, to enhance its recommendations and conclusions for the EIMI-Study Book, a 2-day Workshop was hosted by the University of Macau, China, on November 3–4, 2011. In view of the increasing connections between innovation, science and mathematics, the global need for an analysis and a reflection on strategies for the education and training of new generations was reaffirmed in this Asian meeting that had the participation of six members of the EIMI International Program Committee. The contribution of Li Tatsien in this book also originated from this workshop.

In order to develop the Study Book, the Working Group coordinators were asked to give a written report on their Working Group and suggest papers for inclusion into the Study Book. With this information and in consultation with the coordinators (using sometimes difficult communication channels), the editors finally condensed the Study Book to its present form.

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