Organisation for Economic Co-operation and Development
Global Science Forum

Report on Mechanisms for Promoting Mathematics-in-Industry

Submitted by the Global Science Forum Experts Group on Mathematics in Industry

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Executive Summary.

This report is intended to be read as a corollary to the report "Mathematics-in-Industry" (http://www.oecd.org/dataoecd/47/1/41019441.pdf July 2008). It primarily comprises a factual catalogue of the ways in which the various mechanisms cited in that report have been implemented around the world. The catalogue, which is not comprehensive, has been compiled with the aim of helping governments, industries and academia to see how they may best exploit mathematics as an industrial resource for both research and training.

Introduction

The report (http://www.oecd.org/dataoecd/47/1/41019441.pdf) gave a comprehensive strategic overview of mathematics-in-industry (MI) in this decade. It described the intellectual, economic and societal aspects of this area of activity and many of its implications. The primary aim of this corollary is to provide a clear and accessible list of the mechanisms for promoting MI that were cited in Section 4.1 of the 2008 report. More precisely, the remit of the Experts Group charged with writing the report is to classify proven successful mechanisms according to

- Implementation/Operation
- Overall characteristics and scope
- Types of problems addressed
- Organisation/Management
- Funding
- Time scales
- IP issues
- Numbers of people involved
- Hurdles, pitfalls
- Examples of success stories
- Further Evolution

and any other relevant attributes. However, we will find that not all these considerations will be relevant to each mechanism.

The report will end with a brief "horizon-scan" of the wider implications of mathematics-in-industry.

Two general points need to be emphasised before we embark on our catalogue.

- As cited in the 2008 report, some of the most dramatic mathematical contributions to industrial research have come about as the result of casual unmanaged interactions between individuals from different communities. However, the chances of mathematics bringing valuable new lateral thinking to bear on industrial problems can be greatly enhanced by bringing appropriate coordinating mechanisms to bear. Also, since industrial research is interdisciplinary by definition, all the appropriate mechanisms need to involve not just mathematicians, but also researchers in other areas, both in academia and industry, who are sympathetic to mathematics.

- Since most of the people involved in compiling this report are affiliated to academic institutions, the academic perspective is now emphasised more than was the case in the 2008 report. Hence, there is no mention here of the numerous interesting mechanisms involving mathematical research within industry, including spin-off and consultancy companies.

We will now present our list of mechanisms, illustrated by examples which have been assembled by members of the Experts Group named in Appendix I together with numerous colleagues. The report has also been sent to the group responsible for the 2008 report, named in Appendix II.

Although much (but not all) mathematics-in-industry concerns problem-driven intellectual activity, much of this activity is organised from academia. Hence, the list is divided into Part I, which concerns mechanisms centred around the academic community, and Part II, which concerns mechanisms in which academic and industrial researchers are involved more or less equally.

I. ACADEMIC INITIATIVES

I.1 Interdisciplinary Research Centres within Academia

Academic Research Centres, even if only funded over limited timescales, are necessarily expensive and their establishment may require groundwork over a period of years. They all have mission statements concerning the promotion of mathematics-in-industry, more or less formal management committees and a mixture of senior faculty, post docs, and graduate students. Examples are given country by country with details of centres with which the Experts Group is familiar. We emphasise that we only list centres whose focus is on mathematics-in-industry; there are many more general interdisciplinary centres in which there is a MI component.

Country	Centre + Website	Dates	Funding	Other Comments
Australia	CIAM Adelaide www.unisa.edu.au/ciam	1995 -		18 faculty. 15 post docs. 28 post graduate students.
Austria	IMCC Linz www.mathconsult.co.at/imcc	2002 -	Government/Industry co-funding.	
Canada	IIMS Winnipeg www.umanitoba.ca/institutes/IIMS	2005 -		
China	Basement for Mathematical Modelling Zhejiang University, Hangzhou www.css.zju.edu.cn/mmb			
	FIAMP Shanghai http://math.fudan.edu.cn	2006 -	10^6 Y China NSF.	
	IAM (Chinese Academy of Science), Beijing http://english.amt.ac.cn:8080/iam/			
Germany	ITWM Kaiserslautern www.itwm.fhg.de/	1995 -	50% Industry. 50% Government. €14 million p.a.	30 tenured. 70 post docs. 60 Ph.D
	MATHEON Berlin www.matheon.de/ Involves 3 universities and 2 institutes in Berlin.	2007 -	Government.	Involvement with Berlin Study Group and with 8 universities in Germany.
	SCAI Bonn www.scai.fraunhofer.de	2001 -	50% Industry. 50% Government.	Focus on algorithms.
	ZeTeM Bremen www.zetem.uni-bremen.de/	1997 -		
India	GI²M Baroda www.msubaroda.ac.in/	1983 -		Organises meetings and industrial projects for research collaboration. Links with IIT Bombay.
	IMG, IIT Bombay http://www.math.iitb.ac.in/rd/img/	Launched in 90's	Mainly government funding and UNESCO.	Members of IMG come from Maths and Engineering Depts.
Ireland	MACSI Limerick www.macsi.ie/	2007 -	$4x10^6$ € for 5 years. Irish Government.	
Italy	ADAMSS Milano http://siren.dsi.unimi.it/ADAMSS	2005 -		Successor to MIRIAM.
	I2T3 Florence www.i2t3.unifi.it	2000 -	Institutions in Tuscany and Industry in Florence. Many SMES Involved.	Managed by University of Florence faculty and students.
	MOX Milano http://mox.polimi.it	2001 -	Industrial supported. €1M for 2009.	30 researchers. 20 students.
Japan	MRIT Fukuoka www.mrit.kyushu-u.ac.jp/index-en.php	2006 -	Kyushu University. MI Consortium. MEXT. GCOE Program.	17 researchers. 5 visiting researchers.
	MI MS Tokyo http://www.mims.meiji.ac.jp/index-e.html	2008-	MEXT GCOE Program.	
Netherlands	LIME, Eindhoven www.lime.tue.nl			
New Zealand	CMI Auckland www.mathsinindustry.co.nz	2003 -	50% industry.	Outreach to Thailand, Malaysia, Korea.
Spain	CESGA Santiago	1993 -	Joint	

	www.cesga.es		Industry/Government.	
Sweden	Fraunhofer-Chalmers Gothenberg www.fcc.chalmers.se/	2002 -	€3,000k p.a. 50% from Industry.	Association with ITWM, 30 researchers.
UK	OCIAM Oxford www2.maths.ox.ac.uk/ociam/	1989 -	Oxford University.	15 tenured. 20 untenured. 30 Ph.D.
USA	CIM Milwaukee www.uwm.edu/Dept/CIM/	1999 – 2007		Ongoing M.Sc in Industrial Mathematics.
	CIMS Worcester www.wpi.edu/Academics/Depts/Math/CIMS	1997 -	Government, foundations, industry.	Hosts regular Study Groups (see II.2)
	DIMACS Rutgers http://dimacs.rutgers.edu/	1989 -	1989-2000 $\$22x10^6$ from NSF over. 11 years. Now supported with a variety of grants.	Responsive to Government security issues. 300 affiliated scientists.
	IMA Minneapolis www.ima.umn.edu/industrial	1982 -	Industrial Membership 10K p.a. NSF funding for Postdocs.	4 post docs at any one time.
	IMI Columbia, SC http://imi.cas.sc.edu/IMI	1997 -		20 faculty. 8 post docs. 6 post graduate students.
	MCIM Minneapolis www.math.umn.edu/mcim/	1994 -	Initially from University of Minnesota, NSF. Now self-funding.	6 faculty. 20 postgraduate students.

General Comments

We re-emphasise that there are tens of active and evolving MI groups working within interdisciplinary or mathematical research centres around the world and which are not included here.

Many centres rely, at least in part, on large government grants and hence much time is spent on renewal proposals. Another corollary is that the establishment of such centres is critically dependent on the mathematical ethos within the country concerned and the presence of a strong leadership team.

Centres can usually only obtain small sums from industry for specific projects (as distinct from some maths finance centres). They also rely on either skilled faculty or on hiring facilitators (II.6 of this report) to maintain their industrial interface and their collaborative activities.

The great common benefit that these Centres offer is the multitude of academic and industrial scientific interactions that they generate; this not only increases the mathematical productivity of the members of the Centres, and its practical relevance, but it avoids duplication and enhances networking with remote researchers. Moreover, the Centres offer vital first contact points for industrial researchers seeking mathematical advice.

I.2 Targeted Academic Positions

The idea of appointments specifically in mathematics-in-industry is a relatively new concept and it is heavily constrained by the rarity of people with both industrial experience and academic credentials at an appropriately high level.

Country	Institution	Position	Duration	Funding	Uptake p.a.	Comments
Canada	Any Canadian University	NSERC Industrial Chairs www.nserc-crsng.gc.ca/	5 years	$150K CAD	None so far in maths.	
	Any Canadian University	NSERC Industrial R+D Fellowships www.nserc-crsng.gc.ca/	3 years	$30K CAD	Minimal in mathematics.	
Finland	University of Helsinki	Professor of Industrial Mathematics	5 years		Not yet filled.	
Japan	Faculty of Mathematics, Kyushu University	MI Research Fellow MI Assistant Professor http://gcoe-mi.jp/english/	2 years 4 years	MEXT Global COE "Math-for-Industry", Kyushu University		Almost filled
Korea	KAIST Seoul http://mathsci.kaist.ac.kr/mathsci_eng/	Visiting Professorships of Applied Mathematics (Industrial Emphasis)	1 year	Government		Teams of 5 contribute in rotation to post graduate programme.
New Zealand	Massey University Albany http://iims.massey.ac.nz	Professor of Industrial Mathematics	9 years	50% from contracts		Assistant position also offered.
Spain	CRM Barcelona www.crm.es/	Senior Research Position in Industrial Mathematics	Tenure track.			Not yet filled. Intention to build group.
UK	Any UK University	RS Industry Fellows (2 way industry-academe) http://royalsociety.org/	2 years or pro-rata.	£10^6 p.a. for 80 people	10 p.a. are for mathematicians.	Hard to attract industrialists. Operates across all universities and top 700 industries.
	Any UK University	1851 Exhibition Commission (2 way industry-academe) www.royalcommission1851.org.uk	3 years	£80k p.a. per person	4 or 5 are mathematicians p.a.	Hard to attract industrialists. Operates across all universities and top 700 industries.
USA	IMA Industrial Postdoctoral Fellowships www.ima.umn.edu/people/all-ind-postdocs.html	Holders devote 50% effort working with industrial scientists and 50% effort on a combination of their own research and the IMA activities.	Started in 1990	2 years	Funded jointly by the IMA and an industrial sponsor	US

General Comments

It is easier to persuade academics than industrial researchers to apply for targeted positions. This reflects salary disparity to a large extent. However, these positions can act as key focal points and several countries such as Portugal would like to establish them. The rarity of candidates makes it inevitable that many appointments are made *ad hominem*.

I.3 Curriculum Reform and Student Projects

In many countries and for various reasons, universities are unable to offer courses on the applications of mathematics in the real world, with the result that students are unable to realise the societal value of their mathematical skills. This situation can be remedied relatively easily by allowing industrial projects to be part of the curriculum and by curriculum reform. Here we will mostly consider these possibilities at graduate level. The activities below are divided into doctoral programmes with industrial projects, and masters training.

Country /Region	Activity	Duration	Cost/Funding	Comments
	Ph.D			
Canada	Industrial Maths Degrees www.mitacs.math.ca	3 years.	MITACS support.	
Japan	Kyushu University Graduate School of Functional Mathematics www.math.kyushu-u.ac.jp/english/index.php	3 years. 2006 -	Ph.D grant: MEXT Global COE "Math-for-Industry", Kyushu University.	Faculty of Mathematics.
	Graduate School of Mathematical Sciences, The University of Tokyo http://www.ms.u-tokyo.ac.jp/index.html	3 years.	MEXT Global COE Program "The Research and Training Center for New Development in Mathematics University of Tokyo www.ms.u-tokyo.ac.jp/gcoe_e/index_e.html	
Netherlands	TU Eindhoven www.win.tue.nl	3-4 years PhD project.	€80K p.a. split between industry and university.	Employed by university but most of time is spend in company.
UK	EPSRC "CASE" awards www.epsrc.ac.uk	3.5 years.	Ph.D grant: 3/1 government industry.	Joint supervision.
USA	Claremont Graduate University www.cgu.edu/pages/1087.asp	5 years.		Includes industrial projects.
	MCIM www.math.umn.edu/mcim/	1994 -	University of Minnesota.	Graduate training in MI including internships.
	Masters/Diplomas			
Canada	York University M.Sc in Applied and Industrial Mathematics www.yorku.ca	1-2 years.		
Germany	ZeTeM Bremen www.zetem.uni-bremen.de/zetemalt/	2002 -		Industrial modelling seminars.
India	MSc in Industrial Mathematics and Scientific Computing IIT Madras http://mat.iitm.ac.in			
Japan	Kyushu University Graduate School of Mathematics MMA (Master of Mathematics Administration) http://www.math.kyushu-u.ac.jp/english/index.php	2 years. 2009 -	Training Program of Ph.D. and new Master's in Mathematics as Required by Industry (MEXT).	Faculty of Mathematics.
Norway	Masters in Industrial Mathematics NTNU www.ntnu.no/studies/indmat	5 years.		
New Zealand	Massey Albany M.Sc in Industrial Mathematics and Statistics http://albany.massey.ac.nz/	To start 2010		
UK	Bath, M.Sc in Modern Applications of Mathematics www.bath.ac.uk	1 year full time or 2 years part time.	Some EPSRC funding in past, future uncertain.	
	Oxford, M.Sc in Mathematical Modelling and Scientific Computing www.comlab.ox.ac.uk/teaching/MScMMSC/	1 year.	EPSRC: 6-10 grants/year since 1978.	Spawned M.Sc in Mathematical and Computational Finance 2007.
	Reading, M.Sc in Mathematics for Scientific and Industrial Computation http://www.reading.ac.uk/maths/pg-taught/maths-pgtscientificandindustrialcomputation.asp	1 year.		

USA	Harvey Mudd College www.math.hmc.edu/program/			All senior math majors must complete a senior thesis or a math clinic project (see II.4).
	Michigan State, M.Sc in Industrial Maths http://www.math.msu.edu/Academic_Programs/graduate/msim/Default.aspx			
Europe	ECMI Diploma http://www.ecmi-indmath.org/	2 years. 1986-2008		Transnational qualification started in 1986. Superseded by growth of dedicated masters courses.
	ECMIMIM http://www.uc3m.es/portal/page/portal/postgrado_mast_doct/masters/Masters_in_industrial_mathematics/Project	2007-10	€250K from EC.	Transnational grant from EC to develop joint degrees.
	ESIM www.win.tue.nl/esim/		ERASMUS MUNDUS http://eacea.ec.europa/erasmus_mundus	Joint Masters degrees.

General Comments

This is one of the most variegated aspects of MI training, and different communities find it convenient to treat it in different ways. What is remarkable is the way that such training mechanisms can slowly enhance the ethos of MI over quite large communities. This has been true in Europe, where the evolving ECMI initiatives have led to much curriculum development involving industrial projects, joint degrees and MI masters courses. There are also several undergraduate degrees in industrial mathematics in Canada and USA and a detailed study on "Educational Interfaces between Mathematics and Industry" is currently being prepared under the auspices of ICMI (www.icimieimi.wordpress.com) and ICIAM (www.iciam.org).

I.4 Student Modelling Weeks

The early realisation of the attractiveness of mathematics-in-industry to both undergraduate and graduates has made Modelling Weeks one of the most popular MI events organised by academics; in this context "modelling" mainly means the formulation of industrial problems in mathematical terms, but emphasis is also laid on mathematical and numerical analysis and on validation. For many students, participation in a Modelling Week is their first experience of seeing mathematics being put to practical use.

The typical format is for about 5 students per mentor to work in teams on carefully prepared problems presented by the mentors on the first day and to report back on the last day.

Country or Continent	Organisation management	Length	# Students	Cost/Funding
Argentina	Buenos Aires Joint Steel Industry/University.	2010 2 weeks.	40 Joint Industry/Academic.	Kick-start to research programme.
Canada	GIMMC/PIMS http://www.pims.math.ca/industrial/industrial-problem-solving-workshops	1998 - 1 week before Study Group (sec II.2).	30 graduates/postdocs.	$50K CAD
	BC Industrial Maths Summer School www.mitacs.ca/conferences/IMSS2008	4 weeks Annual.	30 undergraduates.	$100K CAD, MITACS and Industry.
China	Mathematical Contest for Modelling www.shumo.com www.mcm.edu.cn	Annual.	5000 teams, 10 undergraduate students in each team.	
India	IIT Madras http://mat.iitm.ac.in	2 months every other year.	100 students. Includes 2 modelling weeks.	Some help from Kaiserslautern.
Mexico	ITAM, Mexico City http://laberintos.itam.mx/files/290.pdf	1 p.a. 1998 -	20 students. 4 problems.	Followed on from two Study Group meetings in Mexico in 1996, 1998.
Netherlands	TU Eindhoven www.win.tue.nl/oowi	1 week 2 p.a.	30 students. 6 problems.	Each week is in partnership with one company. Managed by Industrial Mathematics Department for their Masters students.
Poland	IMPAN Polish Academy of Sciences, Warsaw www.impan.pl/EN/	2-3 months camp. Annual.	40 start. 20 finish.	€30K Joint Industry/Academic.
Spain	University Complutense Madrid http://www.mat.ucm.es/momat/2008mw/2008mw-e.htm	1 week annual. 2007 -	Local M.Sc students.	
	UPC Barcelona http://www-fme.upc.es/gemt/	3 days p.a.	25	€6000 from CRM.

UK	Nottingham/Oxford Universities	1 week. 2009 -	30 graduates.	London Maths Society/ King Abdullah University of Science and Technology.
USA	GSMM camp www.math.rpi.edu/GSMMcamp	2004 – 1 week before MPI workshop (see II.2).	30	NSF funded, based on Canadian GIMMC.
	IPAM (RIPS) Los Angeles www.ipam.ucla.edu/programs/rips2009/	2 months. Since 2001.	NSF and Industry. $400K p.a.	Industrial projects for undergraduate students worldwide.
	Mathematical Contest in Modelling www.comap.com/undergraduate/contests	1988 – Annual.	Several hundred Teams.	COMAP and SIAM.
	North Carolina State University modelling week http://www.ncsu.edu/crsc/imsm/	1995 -		
	IMA Industrial Math Modelling for Graduate Students http://www.ima.umn.edu/industrial/	1994 – Annual.	36 students in small teams. 10 days.	
	SIAM M^3 Challenge http://m3challenge.siam.org	2006 -	Annual. Several hundred teams	Moody's Foundation.
Europe	ECMI www.ecmi-indmath.org/ Rotates around ECMI Centres.	1 week annual. 1988 -	40 invited from ECMI Centres.	€20k EC funding under ERASMUS 1988-2006, now ad hoc.

General Comments

All Modelling Week organisers emphasise the phenomenal enthusiasm that mathematics students display for such events. Indeed there are many examples where participation in groups working at a Modelling Week has changed a student's entire career path. The fact that they are a training activity makes them relatively easy to fund and organise, and in some countries, they are a compulsory part of a masters course. They are also becoming a pre-requisite for students who want to participate in Workshops and Study Groups where the problems are real and not pre-processed.

I.5 Conferences

Traditional research conferences with an MI theme play an important role in creating networks among the global MI community. Their main role is to disseminate new theoretical ideas and practical implications resulting from industrial collaboration of all kinds.

Country/Region	Title	Frequency	Participants	Organisation
China	China Modelling Conference	2 years since 1987.	600	Local. Last one in Sichuan, 2007.
USA	SIAM Mathematics for Industry Conferences www.siam.org/meetings/mi09/index.php	2 years since 2003.	200	SIAM Committee.
Europe	ECMI Research Conference www.ecmi2008.org	2 years since 1985.	3-500	International Committee.
Global	ICIAM www.iciam2011.com	4 years since 1987.	2-3,000	International Committee.

General Comments

Even though these conferences are not usually cost effective for industrial participants, they play a key role in informing the MI community about best practice around the world, and in helping to coordinate this practice. For example, the most recent ICIAM conference was instrumental in promoting the international website MIIS (see II.7).

II. ACADEMIC – INDUSTRIAL COLLABORATION

II.1 Workshops

Perhaps the most responsive mode in which academics can react to industry driven problems is via the rapid implementation of a small short informal workshop. In such workshops, a problem or class of problems is presented by researchers from industry, and relevant mathematical methodologies may be proposed by the academics. Breakout sessions may follow but there should always be a conclusion that highlights the insights and opportunities that have been revealed and leads to a written report.

Country	Organisation	Duration	Cost/Funding	Management
Canada	CRM Montreal www.crm.umontreal.ca Fields Toronto www.fields.utoronto.ca MITACS www.mitacs.math.ca PIMS Vancouver www.pims.math.ca	60-70 workshops/conferences p.a.	National and Provincial Government. $20k for a 5 day event.	Managed industry workshops appear in the overall programme of each institution.
Japan	The Research and Training Center for New Development in Mathematics University of Tokyo www.ms.u-tokyo.ac.jp/gcoe_e/index_e.html	Once p.a. “Industrial Mathematics and its Practice” http://www.ms.u-tokyo.ac.jp/documents/program20090217.pdf	MEXT Global COE Program.	University of Tokyo. Many MI events p.a. sponsored by Global COE program. www.gcoe-mi.jp/english
	Forum“ Math-for-Industry” Kyushu University http://gcoe-mi.jp/english/	Once p.a.	Kyushu University and MEXT.	Faculty of Mathematics.
Norway	CMA, Oslo University www.cma.uio.no	2 workshops p.a.		In collaboration with SINTEF.
Spain	CESGA www.cesga.es	Regular.	Local.	Project Identification, Road-mapping.
UK	KTN Themed Workshops www.industrialmaths.net	1 or 2 days. 4 p.a.	£1000	Reliant on technology translators, up to 6 months lead time.
	OCIAM Oxford www.maths.ox.ac.uk/ociam/	1 day. Every 4 weeks.	Minimal.	Reliant on a technology translator.
USA	IMA Industrial Problems Seminar www.ima.umn.edu/industrial/2008-2009/	15 talks by industry speakers p.a. since 1988.		

General Comments

These events are focussed and usually industry-driven and they require good judgement from both industrial and academic researchers to ensure that the topics are appropriate. They are highly interdisciplinary and often heavily reliant on the presence of a “technology translator” or “research facilitator” (see (II.6)). Indeed such people are often the only ones who can write a report that will be of subsequent value to both communities. The reports can also be used to inform government or research agencies concerning research strategies.

II.2 Study Groups

Study Groups are a regular and growing feature of the MI scene worldwide. The usual recipe is for a group of 4 to 10 industrial researchers to present problems to an audience of academic mathematical scientists (including students) on day 1. The key feature is that the academics, who should average about 10 per problem, then gravitate to whichever problem(s) interest them most and then brainstorm with the industrialists in individual rooms over the next 2-3 days. The reporting back session is on the final day and ideally a report is written for each industrialist within a month or two of the end of the Study Group.

There are many individual variations on this theme:

- "Moderators" may be appointed beforehand to facilitate the discussion prior to and during the Study Group
- Preliminary reporting back may take place mid-way through the Study Group to keep all participants alerted.
- Study Groups may be open to any industry, or they maybe "in-house", with corresponding IP relaxation. However IP constraints severely restrict the likelihood of successful brainstorming sessions.
- Companies may or may not be charged registration to cover academics' costs.

Country	Venue and Timing	Cost	Numbers	Organisation	Local Variations
Australia/ New Zealand	Rotates around universities. Annual since 1985.		10 problems. 100 participants.	Originally supported by CSIRO, now local faculty.	Originally in Australia, first NZ meeting 2004. www.maths-in-industry.org/
Canada	Various venues on West and East Coasts. Annual since 1997 sometimes thrice annually, now twice.	Supported by PIMS, Fields, CRM $40K. Registration fee charged.	6 problems. 60 academics.	Committees at local centres /universities.	Many companies return. Efforts being made to achieve national coordination. Heavy reliance on pre-Study Group modelling week for students (see I.4). www.maths-in-industry.org/
China	Fudan University, City University of Hong Kong, Universities of Hangzhou, Zhengzhou, Nanjing. Annually since 2001.		10 problems. 100 academics.	Local universities. FIAMP Fudan is nerve centre. http://math.fudan.edu.cn	Spawned "in house" Study Groups with Bao Steel and workshops on oil recovery, steel, earthquakes and finance.
Denmark	3 universities Annual since 1999.		3-6 problems. 30-50 academics.	Local.	Part of ESGI series. www.maths-in-industry.org/

France	EIGSI La Rochelle http://bar3d.eigsi.fr 2005		3 problems.	Local.	Study Group/Workshops focusing on Maritime Pollution.
	Various companies with Corporate Laboratories over past 10 years (initially St. Gobain).		5 problems. 30 academics.	Within company.	Companies found it very useful to have report by the end of the Study Group.
Germany	WIAS/ MATHEON Berlin www.matheon.de www.wias-berlin.de	€12K	5 problems. 50 academics.	Local universities.	Focus on specific industrial areas, co-organisers for those areas. Stimulated "Transfer Unit" in MATHEON.
India	IIT Mumbai MSU Baroda. Biannual since 2004.	Initially supported by UK Royal Society	10-15 problems. 100 academics.	Local universities. Coordination from IIT Mumbai.	See I.1 for website. 2009 meeting in IIT Roorkee.
Ireland	Limerick. Annual from 2008.	MACSI www.macsi.ie/	7-8 problems. 60 academics.	Local committees and technology translator.	Part of ESGI series www.maths-in-industry.org/
Netherlands	Rotates. Annual since 2000.		5-7 problems. 50 academia.	Local.	Part of ESGI series. www.maths-in-industry.org/
Portugal	Various Universities. Annual from 2007.	Supported by CIM on 2 occasions. www.cim.pt	2-4 problems. 20-30 academics.	Local committee and experience from earlier meetings.	Need for national coordination. Part of ESGI series www.maths-in-industry.org/
Spain	GEMT Barcelona http://www-fme.upc.es/gemt/ 2001 – 5 meetings so far.	€3K from UPC. Support from CRM.	3 problems. 35 people.	Local.	Mainly local participants.
South Africa	University of Witwatersrand	£14k from Witwatersrand. No registration.	10 problems. 70 academics.	Local committee.	Acts as transcontinental resource for staff and students. Strong training emphasis. For outcomes, see http://web.wits.ac.za/NewsRoom/Conferences/MISGSA2008/Outcomes.htm
UK	Any University that offers. Annual since 1968.	£30k £5k registration fee for each industry.	6-8 problems. 70 participants.	Local faculty aided by technology translator from KTN (see II.5).	Cheaper for SME's, first time participants. Incorporated as part of ESGI. www.maths-in-industry.org/
	Schlumberger Labs., Oxford, and Cambridge. Spasmodic.	£40k	5 problems from Schlumberger. 20 academics.	Schlumberger staff.	No IP. Dedicated organiser essential. Senior management support crucial 7 months lead time. Spawned Texas meeting.
USA	Several East Coast Universities. Annual since 1985.	Originally funded by Sloan Foundation. Registration fee for Industry.	4-5 problems. 50 academics.	Local faculty. Challenge for the workshop is to expand participation with industry.	One off meetings held in Harvard and Los Alamos. http://eaton.math.rpi.edu/Faculty/Schwendeman/Workshop/MPI.html
	IPAM, UCLA 2003		8 Problems. 50 academics.	International committee.	Inverse Problems: Industrial Problems Study Group. http://www.ipam.ucla.edu/programs/invip/
	Schlumberger Sugarland 2006	$50K	6 problems. 50 academics.	Schlumberger Staff.	As in UK.

General Comments

Almost all Study Group organisers have commented on the key training benefits that accompany the research progress. As with modelling weeks, which closely compliment the Study Groups, this kind of activity uniquely opens young researchers' eyes to the possibilities of using their mathematical talents outside of mathematics. The key intellectual ingredient of the Study Groups is the freedom they give to allow academics to work on the problems that excite them most strongly. The impact that they have can result in network and centre nucleation, and their value to industry can be assessed from the frequency of repeat business.

One problem has been the difficulty of producing reports for industrialists in a timely fashion, but this can be alleviated by the involvement of dedicated research facilitation and/or technology translators. Under extreme industrial pressure, the reports can be provided instantaneously.

The globality of the Study Groups community helps give this mechanism stability and coherence independently of language and mathematical ethos. Intellectual connectivity is now greatly enhanced by the website MIIS (www.math-in-industry.org; see II.7 where much more information is available).

II.3 Internships

The concept of Internships is relatively new in MI even though it has been used widely in other scientific disciplines, including mathematics, at undergraduate and graduate level. Since the innovative deployment of MI internships in Canada, the concept is gaining popularity by leaps and bounds and it is even being seen as a paradigm for interdisciplinary post-graduate research across disciplines other than mathematics.

Country	Organisation	Cost	Numbers	Duration	Local Variation
Australia	AMSI www.amsi.org.au/Industry_internships.php/	$15K AUD from industry + $5K AUD from AMSI.	5 in 2007/8.	4 months.	
Canada	MITACS www.mitacs.math.ca, with dedicated staff started in BC in 2003. Supplies support and receives $5k per project.	50% MITACS 50% Industry. Faculty advisor gets $15K CAD. $10K CAD supports students.	Growth from 10 in 2003 to 620 in 2009 (not all in maths).	4 months.	62% repeat business. IP template provided.
Germany	MATHEON www.matheon.de/transfer/internships.asp?lang=en	Student stipend + €5K to supervisor.	7 in 2008.	6 weeks – 3 months.	
Japan	Kyushu University www.math.kyushu-u.ac.jp/english/index.php	Supports: 90% Industry 10% Global COE (MEXT) "Math-for-Industry", Kyushu University	Started in 2006. about 10 students p.a.	3-6 months or more.	
Netherlands	TU Eindhoven www.win.tue.nl/oowi	€20K to company.		7 months.	Part of a 2 year masters programme. IP owned by company.
UK	KTN www.industrialmaths.net with dedicated staff	Roughly 50% EPSRC/Industry joint funding.	Growth from 6 in 2007 to 30 in 2009.	3-6 months.	Sliding time and funding scales.

General Comments

Internships have caught the international MI imagination possibly because of their potential for rapid growth, the enthusiasm with which industry and graduate students embrace them, and the corresponding ease of implementation. Amongst other countries keen to adopt internships are Portugal and Ireland. Also there is a vast undergraduate internships scheme at Waterloo, Canada in which 3000 out of 5000 students taking maths enrol with 97% success in placements. This scheme depends on a student cooperative fee. Many large industries organise an in-house internship scheme, a few percent of which will be mathematics oriented, and this can cause a competitive situation.

II.4 Team-working

The activities under almost all the headings in this report, especially I.3 and I.4, involve team-working in some shape or form. However, there is one mechanism that relies entirely on teamwork and it follows the pioneering initiative of "Industry Clinics" at Claremont, California. For organisations large and resourceful enough to support team working initiatives, there is the great advantage of being able to build academic-industrial relationships which can last over many years. The scheme is distinctive in that close collaboration is maintained with the industry throughout the lifetime of the clinic.

Country	Organisation	Time Scale	Cost	Management	Comments
USA	Claremont Colleges Mathematics Clinics www.math.hmc.edu/clinic www.cgu.edu/pages/2704.asp	Annually since 1973. Since then 237 projects (each 2 semesters). 80 sponsors.	$45K per project. $300 k p.a.	Each team consists 1 faculty, 4 students and 1 liaison. Managed by 1 Clinic Director, 1admin, 1 computer aid Across Campus.	Steady repeat business. IP belongs to the sponsor.

General Comments

The Maths Clinics idea is an ambitious mechanism, requiring a large commitment from both academia and industry. It is especially beneficial to stable industries with long term research programmes.

II.5 Networks

The diverse and unpredictable nature of industrial research means that problems suitable for mathematical treatment arise around the world randomly in time and space. One way for the mathematics community to respond to this scenario is through MI networks, so that if an industrial problem in a certain scientific area is identified by a mathematician who is not expert in that area, wider mathematical resources can immediately be mobilised. Efficient networks need to be professionally managed if they are to be responsive and knowledgeable enough to make good "marriages" between industry and academia on a regular basis.

Country/ Region	Mode of Operation	Time	Cost	Numbers of People	Management
Australia	AMSI Network of academic institutions and some corporate members. Runs internships, workshops, summer schools. www.amsi.org.au	2003 -		35 member institutions.	Director and committee structure.
Canada	MITACS Network of Centres of Excellence (see II.3) www.mitacs.math.ca Originated internships on large scale.	1998 - 2012	5x10^6 CAD p.a. from National Government. 5x10^6 CAD p.a. from Provincial Government. 6x10^6 CAD p.a. from industry.	36 projects. 475 academics. 1000 students. 320 non-academic organisations.	Executive + International committees. Strong links with Fields, PIMS, etc (see II.1).
Germany	Math&Industry www.mathematik-21.de	1993 - 2010	€48,9M from National Government (BMBF).	267 projects in total.	PtJ – Project Management Juelich. http://www.fz-juelich.de/ptj/mathematik
Spain	i-math www.i-math.org	2006-11	€7.5 million.	50 academic institutions and many industries.	Road-mapping etc.
UK	KTN/Smith Institute evolved from 2 smaller predecessors Runs workshops, Study Groups etc Liaises with 2 UK Government Funding Agencies www.industrialmaths.net (e.g. annual Inverse Problems workshop, Leeds)	1993 -	50/50 Government/Industry consulting. £10^6 p.a.	Researchers in 40 UK universities.	10 technology translators (see II.6) + management council + scientific committee + industrial advisory board.
USA	IMA Minneapolis. Network of affiliated companies. www.ima.umn.edu/industrial	1990 -	$10K membership.	50	Offers shared workshops, introductions etc.
Europe	ECMI Network of Institutions, not people www.ecmi-indmath.org	1984 -	Membership fee €150 p.a. Administrative costs only.	100 member institutions.	Committee structure to organise newsletter, conferences, modelling weeks, student exchanges, joint degrees.
	MACSINET Europe-wide research EC coordination to setup working groups and workshop series www.macsinet.org	2000-2006	€500K from EC for workshops, road maps etc.	Up to 100 in Special Interest Groups.	Transnational committee of 20 academic and industrialists.
	NETIAM EC sponsored network to explore new challenges for MI. www.smithinst.ac.uk/projects/NETIAM	2004 - 6	€100K from EC.	5 workshops, 20 people each.	Needed careful liaison with EC.

General Comments

Networks have proved themselves indispensible in many countries where MI is practised on a large scale. In recent years they have become increasingly international, for example by fostering exchange visits between young MI researchers and facilitating their attendance at workshops etc.

Networks are often managed jointly by industrial and academic committees and they are ideally placed to give funding agencies and governments information on regional strengths and weaknesses both in research and training. They have also provided working papers and road maps on which MI strategy decisions may be based. Indeed this report and the July 2008 report were both prepared by ad hoc MI networks.

II.6 Facilitation

When MI began to grow in the second half of the twentieth century, it soon became apparent that the administrative load was increasingly interfering with the intellectual challenges with which academics were being confronted. This led to the concept of "technology translators" or "research facilitators", namely people who usually have research experience both in industry and in academe and whose remit is to

- make introductions;
- look out for funding opportunities;
- help organise workshops, Study Groups, and other collaborative activities and;
- ensure good communication flow between industry and academe and vice versa.

Country	Job Description	Funding	Cost	Distinctiveness
Canada	MITACS Business Development/Strategic Programs Officers www.mitacs.math.ca	Internal to MITACS.	Industrial salary.	Liaise internships. Need not be a mathematician.
China	Technology Translator in FIAMP (see I.1)	FIAMP	Post doc salary.	Organises workshops, industrial contacts.
Ireland	Technology Translator in MACSI (see I.1)	SFI	Post doc salary.	Organises workshops, Study Groups.
UK	KTN Technology Translators www.industrialmaths.net	Government/Industry.	Industrial salary.	Work with industry and UK universities.
	OCIAM Research Facilitator www2.maths.ox.ac.uk/ociam	University. Ongoing since 2001, now 3 posts.	Post doc salary.	Research income increased by 10 times over 6 years.

General Comments

The concept of facilitators who "manage the interface between industry and academia" is attracting more and more attention around the world. However, funding is sometimes a problem because facilitators are neither full-time researchers, nor full-time administrators and thus have no well defined career path. This difficulty can be alleviated by making facilitators part-time consultants, a task for which they are well qualified by definition.

II.7 Publicity

Any activity involving the esoteric art of mathematics is inevitably handicapped when it comes to publicity in the wider world. MI is no exception but it does have the unique advantage of being able to catch the imagination by highlighting examples where the mathematics is mysterious, yet is able to shed light on everyday activities[1]. The most important issue is publicity within the academic and industrial communities, to which the list below is mainly addressed. We have not however had time or space to list the large number of texts, conference proceedings and monographs that have been devoted to MI.

Country	Vehicle	Comments
Canada	MICS Journal (Electronic) www.micsjournal.ca/index.php/mics	Produced by Fields Institute. Editorial board consists of practising MI academics. Aims to publish genuine case studies in learned journal format.
	MITACS website www.mitacs.math.ca	Extensive website including news and media coverage.
Germany	IM-Net http://maja.iwr.uni-heidelberg.de/imnet/	Newsletter.
Japan	Journal of Applied and Industrial Mathematics http://springerlink.com/content/120583/	
	Journal of Mathematics-for-Industry http://gcoe-mi.jp/english/publish_list	Institutional Depository, Kyushu University (Founded on March, 2009).
New Zealand	Massey University www.mathsinindustry.co.nz	Promotes awareness of problem-solving power of mathematics.
UK	KTN website and lobbying www.industrialmaths.net	Committee identifies strategic areas and bring together stakeholders (industry, government, academia).
	MIIS website www.math-in-industry.org	Global publicity concerning past, present and future Study Groups and other events and reports.
USA	SIAM website http://www.siam.org/publicawareness/	
	IMA website www.ima.umn.edu/	

General Comments

Much publicity relies on word of mouth and, increasingly, on material found on the Internet. Indeed, many of the mechanisms in the preceding pages came about by such serendipity. For example, the UK 1851 fellowships resulted from a remark by Prince Philip in 1960, ECMI resulted from an informal gathering in Amsterdam, KTN from a single benefaction, etc. etc.

The very fact that MI is such a collaborative activity is conducive to such serendipity.

[1] In the UK, the Minister of Science was impressed by the insights mathematics could give to cow milking machines, in the US the public press was excited by laundry drying, etc. (Such examples need to be chosen judiciously to avoid "ignobility.")

Conclusion

This report has condensed a vast amount of data concerning the fast-moving MI interface. The global MI community is so large that the report is far from comprehensive, containing, as it does, only information known to the Experts Group, the Heidelberg Group, and their colleagues. Also there are inevitably some historical errors in the tables. However, we hope that, in due course, the report can be put on a database such as MIIS, where it can be continuously updated and managed in a user-friendly way for the use of both academics and industrialists. A Wikipedia-style expansion of MIIS may be useful for this.

The main points that have emerged are:

- Although MI research is usually a problem-driven intellectual activity, much of this activity is currently organised from academia.
- At a time when hardly any industries have corporate laboratories that can sustain mathematics groups, governments provide the main resource for MI; this support is mostly via academia, but when it is provided directly at the interface, it can have a major national impact. In particular, the creation of national and international networks can both stimulate mathematical awareness and creativity concerning industrial problems and avoid duplication of intellectual effort.
- The collaborative activities we have cited mostly emphasise either innovative problem-solving or high-quality training, but progress towards either goal inevitably enhances progress towards the other.

Appendix I

OECD Global Science Forum EXPERTS GROUP ON MATHEMATICS IN INDUSTRY		
Australia/ New Zealand	Graeme Wake	Massey University, New Zealand
Canada	John Stockie	Simon Fraser University
Denmark	Mads Peter Soerensen	Technical University of Denmark
Finland	Mats Gyllenberg	University of Helsinki
	Leo Kärkkäinen	Nokia
Italy	Sandro Salsa	Milano Technical University
Japan	Hiroshi Furuta	Basic and Generic Research Division, MEXT
	Setsuo Taniguchi	Kyushu University
	Masato Wakayama	Kyushu University
	Masahiro Yamamoto	University of Tokyo
	Moritaka Hosotsubo	National Institute of Science and Technology Policy
Netherlands	Jaap den Doelder	Dow Benelux
	Wil Schilders	Eindhoven University of Technology
Norway	Ragnar Winther	University of Oslo
Poland	Marek Niezgódka	University of Warsaw
Portugal	José Francisco Rodrigues	University of Lisbon
Russia	Alexander Skubachevskii	Peoples' Friendship University of Russia
Switzerland	Rolf Jeltsch	Swiss Federal Institute of Technology
United Kingdom	Hilary Ockendon	Oxford Centre for Industrial and Applied Mathematics
	John Ockendon (Chairman)	Oxford Centre for Collaborative and Applied Mathematics
United States	Peter March Weiqing Gu	National Science Foundation National Science Foundation

Appendix II

OECD Global Science Forum
MATHEMATICS IN INDUSTRY

22-24 March, 2007
Heidelberg, Germany

Workshop Participants

Australia	Tim Marchant	University of Wollongong
Austria	Ulrich Langer	Johannes Kepler University Linz
Canada	John Stockie	MITACS
Finland	Mats Gyllenberg	University of Helsinki
	Leo Kärkkäinen	Nokia
France	Jean-Pierre Bourguignon	Institut des Hautes Études Scientifiques
	Doina Cioranescu	Université Pierre et Marie Curie (Paris 6)
	Erich Wimmer	Materials Design
Germany	Hans Georg Bock	IWR, University of Heidelberg
	Martin Grötschel	Zuse Institute Berlin
	Karl-Heinrich Hahn	BASF AG
	Joachim Heinze	Springer
	Ulrich Jaeger	Busverkehr Ostwestfalen GmbH
	Willi Jäger	IWR, University of Heidelberg
	Frank Kiefer	German Research Foundation
	Helmut Kipphan	Print Media Industry
	Rainer Koepke	Federal Ministry of Education and Research
	Hans Joachim Krebs	Forschungszentrum Jülich
	Siegfried Neumann	Merck
	Dirk-Jens Nonnenmacher	DZ Bank
	Friedrich Rippmann	Merck
	Anna Schreieck	BASF AG
	Hermann Schunck	
	Andreas Schuppert	Bayer Technology Services
	Jürgen Sprekels	Weierstrass Institute for Applied Analysis and Stochastics

Italy	Vincenzo Capasso	University of Milan
	Alessandro Cremonesi	STMicroelectronics
	Pierangelo Marcati	University of L'Aquila
Japan	Kazushige Fukuhima	Basic and Generic Research Division, MEXT
	Moritaka Hosotsubo	National Institute of Science and Technology Policy, MEXT
	Shun-ichi Kawanishi	Japan Atomic Energy Agency (JAEA)
	Junichi Nakagawa	Nippon Steel Corporation
	Satoru Ohtake	Basic and Generic Research Division, MEXT
	Masahiro Yamamoto	University of Tokyo
Netherlands	C.F. Jaap den Doelder	Dow Benelux B.V.
	W.H.A. Schilders	TU Eindhoven
Norway	John Reidar Granli	STATOIL
	Ragnar Winther	University of Oslo
OECD	Stefan Michalowski	Global Science Forum
	Takuya Okamoto	Global Science Forum
Poland	Marek Niezgodka	ICM Warsaw
Portugal	José Francisco Rodrigues	University of Lisbon
Russia	Alexander L. Skubachevskii	Peoples' Friendship University of Russia
Spain	Adel Abbas	Airbus
	Luis Bonilla	University Carlos III Madrid (Leganes)
	Jose Manuel Vega	Universidad Politécnica de Madrid
Sweden	Nils Svanstedt	Chalmers University of Technology Göteborg
Switzerland	Rolf Jeltsch	Swiss Federal Institute of Technology, Zurich
Turkey	Orhun Kara	TUBITAK National Research Institute of Electronics and Cryptology (UEKAE)
United Kingdom	Mark Bambury	EPSRC (Mathematical Sciences Programme)
	Hilary Ockendon	Oxford Centre for Industrial and Applied Mathematics
	John Ockendon	Oxford Centre for Industrial and Applied Mathematics
	Heather Tewkesbury	Smith Institute Knowledge Transfer Network
United States	Hans Kaper	National Science Foundation