The ECMI-programme Mathematics for Industry at the Technical University Dresden (1990-2013)

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Introduction

The number of participating universities in the new master-programme of the European Consortium for Mathematics in Industry (ECMI) has remarkably increased. This is a reaction to the great interest in this celebrated form of academic education and shows also that many European universities rely on and adopt the experience the classical ECMI-centres have gained in the past 25 years.

The development, implementation and also some specific features within this process experienced by the Department of Mathematics of the Technical University of Dresden (TUD) were and might be of interest for East-European universities (in particular, for universities from the Baltic states), joining the ECMI-system in recent years. The fact is, that those (technical) universities, in particular, the universities in the former Soviet Union, during the socialist time offered nearly the same five-year Diploma programmes in say, Mathematics and Applied Mathematics, as well as having a strongly structured teaching process and syllabi. In general, for whatever reason, there was no possibility for a student to change the university during their studies nor that several universities offered the same coordinated programme enriched with local specific characteristics.

This contribution will describe the main stages the TUD has gone through from traditional mathematical modelling to the introduction of Technomathematics via two International Conferences devoted to the subject until the ECMI Model Master Programme in Industrial Mathematics/Technomathematics (2011/12) as an umbrella for local master programmes. The establishing of the corresponding programme in Economathematics at the Department has proved to be easier and therefore will be mentioned only marginally.

Mathematical Modelling at the TU Dresden until 1990

The Department of Mathematics of the TUD has long-term experience in Modelling and Applied Mathematics with a participation of the Institutes of Numerical Mathematics, Probability Theory and Stochastics, Geometry, Mathematical Cybernetics and Analysis.

[1] Mathematicians were also involved in research teams set up at technical Departments.

The mathematical modelling and the work for industry at that time was organized in 1-3 year lasting contracts between (technical) universities and enterprises. The dates and deadlines for interim and final reporting were fixed in the contracts. There was also set out the amount of money the university was entitled to receive for its research accomplishment. The industrial partners of the TUD were mostly state held (or people owned) companies such as Robotron Dresden (Microelectronics), Plastic Deformation Technology Erfurt, Machine Tools Karl-Marx-Stadt/Chemnitz, Pharmaceutical Works Dresden, Special Steel Company Freital, Shipbuilding Rostock, regional glass and paper industries, etc.

As a rule the small and middle sized companies were more or less integrated into the state companies. The large scale industry in the country was managed centrally. The so-called key technologies for some period had been defined by the state or/and by the Council for Mutual Economic Assistance (known as Comecon). These main directives were also reflected by the topics in modelling and research in applied mathematics. Those companies disposed with research and development divisions, in which very often our own alumni (diploma holders and people with a doctor's degree) were employed.

Topics modelled, developed and studied by the Department of Mathematics ranged from reliability investigations, quality control, optimal cutting and packing problems, container and pallet loading, gear and linkage geometry to soft- and hardware design, computer aided geometry, problems in forestry, models of special materials etc.

Although some special branches of the East German industry were recognised on the international level, a high competitive capability within the international economy could not be achieved. In general, the increasing state interference slowed down the economic activities and decreased the efficiency, due to a lack of economic incentives the labour productivity was low, many human, research and modelling capacities were bound and constricted (and wasted) by targets like substitution and saving raw material and reinvention of known technologies which, due to the embargo policy, were not accessible or only very difficult to be acquired on the international market.

The applied research and modelling work at the Department of Mathematics was organized and carried out in special research teams (together with members from industry and appropriate technical Departments[1]). At times staff members involved even got a reduction in their teaching loads. In the early 80's of the last century an Application Group was set up, later a Bureau of Applied Mathematics. Staff members could earn a bonus for excellent work in these groups. The students specializing in branches of applied mathematics (after their 2-years of basic studies) were attracted by those groups and so involved in modelling and research work. They had successfully to complete an industrial placement and to write a term paper. Very frequently the industrial problems led to diploma

and even to doctoral theses, where as a rule one supervisor came from the industry.

So, the main conditions and prerequisites for further development of modelling and joining the ECMI-system (i.e. experience in mathematical modelling, collaboration with industry, sufficient number of qualified staff etc.) were basically present in the Department. However, there was no experience neither in postgraduate programmes nor in partial studies abroad or at another university.

1989/1990 and the reunification of Germany

The Technical University Dresden was the first East-European university which was invited (by an initiative of the TU Kaiserslautern in 1990) to collaborate within ECMI. So, as a first step based on what has been exposed in the previous section, there was drafted and introduced the two-year postgraduate ECMI-programme Mathematics for Industry, which was offered for students parallel to the Diploma programme from the 3rd year on.

The Department at that time was faced with the following problems:

- Supply lectures, tutorials and seminars for the postgraduate program, in particular, establish a Modelling Seminar according to the requirement of the ECMI-Programme.
- Organization of selective minor (technical) subjects for students of Mathematics together with students from engineering faculties.
- Teaching in English (only a few foreign students among German ones).
- Build up and renew contacts to industry (internships, industrial problems, report on the modelling of some real-life problem).
- Organize a one-semester stay at another ECMI-centre or at a company abroad.

The transformation process at the TU Dresden 1991 - 1995

The first steps towards the new Diploma programme Technomathematics (5 years) were made in the spirit of ECMI and taken in the subsequent directions.

- The negotiations with the Engineering Faculties (Mechanical, Electrical, Civil Engineering) and Informatics were aimed at developing lectures, seminars and exams (joint for students of Mathematics and Engineering). Each student of Technomathematics had to select one minor technical subject: mechanical engineering, electrical engineering, physics, informatics, environmental, (later) biotechnological sciences. The interest in our request among the Engineering Departments was committed and the discussions ended up with good arrangements.

- Guided by ECMI experience a one semester Modelling Seminar was introduced for students of Technomathematics and Mathematics as well, where real life problems from local industry were modelled in about 5 groups of 2 - 3 students supervised by one instructor each.
  Remark: As a consequence of take-overs and the closing down of companies in the former GDR/East Germany but also as a result of the drastic suspension of staff in the Saxonian university system (the permanent staff was reduced by nearly 60%!) seminars as described above could not be continued anymore. Today at the Department of Mathematics many experienced staff members are totally deployed in the broad spectrum of service lectures and seminars in Mathematics for students of the Engineering Departments. Another problem was that the Modelling Seminar was accepted as the only teaching load for one staff member. Many institutions of higher education in East Europe were and are faced with a similar, hopefully more smooth transformation.

- Good students of Mathematics were permitted to join the parallel ECMI-programme. As a rule this led to an acceptable one or-two term extension of their 5-year Diploma studies. The first ECMI-Certificates were awarded to such students from Dresden.

- Many half-year stays of Dresden's students were organized (and mostly financed by EU's Erasmus and Leonardo programmes) at the ECMI-centres in Linz, Glasgow, Eindhoven, Oxford, Grenoble, Lyngby, Trondheim.

- Students and instructors from the TU Dresden regularly participated in the International ECMI-Modelling Weeks.

The period 1995 - 2007

In 1997 the 10th International ECMI-Modelling Week took place in Dresden.

Until 2001 the ECMI postgraduate programme was implemented as an additional partial study within the, at that time, revised Diploma programmes Mathematics, Technomathematics, Economathematics.

In the period 2000 - 2008, each year about 50 students in Mathematics, 20-25 students of Technomathematics and about 80 in Economathematics were enrolled at the Department.

In 2003, on the occasion of the 125th anniversary of its founding, the TU Dresden organized the International Workshop on the Study Programme Technomathematics.

At its conclusion a Position Paper[2] was signed by 30 Universities from Austria, Czech Republic, Estonia, Germany, Hungary, Latvia, Lithuania, Poland, Russia, Serbia (and Montenegro), Slovenia and Ukraine.

From 2002 until 2005 the successful Tempus-Project (JEP-17017-2002): Development and Implementation of a Masterprogramme for Applied Mathematics at the University of Novi Sad was accomplished with the participating institutions from Dresden (contractor), Lappeenranta, Milano and Zielona Góra.

[2] see: tu-dresden.de/mathematik/ecmi. Available as pdf-file

The rich experience of ECMI and the compatibility with the ECMI-programme were important in the realization of this project. The results have been evaluated positively by the EU.

Since 2003 the Novi Sad University has taken part in the activities of the ECMI-Educational Committee as an associate member.

From 2007 on towards the ECMI Model Master Program

At the Department the study programmes Mathematics, Technomathematics and Economathematics had to be reorganized and adapted according to the Bachelor-Master System, where the Bachelor syllabus is unique for all programmes.

From 2009 onwards the number of students enrolled for all Bachelor programmes has decreased and has now reached the level of around 75 each year. For a student's further orientation and specialization in Technomathematics (TM) or Economathematics (WM) their minor subject can be selected from Informatics, Physics, Mechanical or Electrical Engineering or different Economy subjects etc. as well as a unit in Mathematical Modelling and Simulation. The content, concept and modularization for the corresponding Master Programme in Technomathematics was directly influenced and developed by the idea and request of the renewed ECMI Model Master (see below). The Modelling Seminar and a one-term project are compulsory parts.

In 2012 there are 18 (3, 9) students who joined the Master Programmes in Mathematics (TM, WM), respectively.

The framework or umbrella programme *European Master Programme in Industrial Mathematics*, as a Model Curriculum was elaborated within the EU-project (134026-LLP-1-2007-1-ES-ERASMUS-ECDSP) jointly by the ECMI-centres Barcelona, Dresden, Lappeenranta, Lund, Madrid (Universidad Carlos III, contractor), Milano, Oxford and the universities Ecole Nationale Superieure de Mines Paris and Tartu.

After the concluding *Dissemination Conference*, held in 2009 in Dresden, these universities signed a Statement[3], which has to be understood as a corner stone towards creating a joint European approach for Industrial Mathematics.

The new programme essentially based on the ECMI ideas has attracted a considerable number of new members in and around ECMI: Lisbon, Coimbra, Sofia, Kiev, St. Petersburg (Polytechnical University).

Together with the Model Master Programme there appeared also new forms of cooperation such as

- Double-Degree agreements between ECMI centres (e.g. Dresden, Lund, Milano)
- Linking the annual ECMI-Modelling Week with a one week Summer School. ECMI-Modelling Weeks extended by Summer Schools already took place in 2009 and 2011 in Milano, 2012 in Dresden and 2013 in Madrid.

For creating a joint European Higher Education Area according to the Bologna Process the 25 years experience of ECMI would have been very helpful. In contrast some guidelines and characteristics of the Bologna Process did not turn the situation into the better, e.g. at the TUD the student's mobility has remarkably decreased, the flexibility in choosing subjects is very restricted.

[3] see: tu-dresden.de/mathematik/ecmi. Available as ps-file

The TU Dresden as an 'Excellence University' in Germany

In 2012 the TU Dresden has been evaluated as one of eleven Universities of Excellence in Germany.

All submitted proposals were approved and will be funded at least to 2017:

- Institutional Strategy "The Synergetic University"
- both proposals for Clusters of Excellence
  - Centre for Advancing Electronics, Dresden
  - Centre for Regenerative Therapies, Dresden
- Dresden International Graduate School for Biomedicine and Bioengineering.

At the TUD there exist now five so called Research Priority Areas:

- Health Sciences, Biomedicine, Bioengineering
- Information Technologies and Microelectronics
- Smart (intelligent) Materials and Structures
- Culture and Knowledge
- Energy and Environment

Mathematics and Modelling, of course, play a remarkable role in all these research areas and the Department is partially involved in several research fields. However, so far the title of Excellence is exclusively concentrated on research only, the impact on the teaching process, in particular, on a necessary increase in the level of modelling has not been seen yet.

Some final remarks

Celebrating the 25th anniversary of the European Consortium for Mathematics in Industry the results and experience of the "classical" ECMI centres and the common ECMI Model Master Programme "Industrial Mathematics" are remarkable and have been highly valued on different occasions. From the point of view of the Department of Mathematics (TUD) some thoughts and remarks seem to be proper and might be of interest for a further discussion.

In order to ensure the main features and to keep the common standards of the joint programme a high responsibility of each participating university is indispensable.

Specification and strength of each particular university should be visible in the ECMI-programme.

To guarantee a high (university) level of education the Quality Management of the ECMI Educational Committee has to be improved. More attention of the latter has to be paid to Controlling, Inspection and Certification of the programme in each centre.

Modelling, together with strengthening the cooperation and interaction with industry, is still a problem for several universities. The question is, how to organize modelling and similar activities for students based on real-life problems (and not only academic ones).

Organize, coordinate and guarantee the student's exchange between the ECMI-centres and European industry.

One recommendation for universities entering ECMI might be the installing of an Endowed Chair (professorship) for Mathematical Modelling (possibly together with Industry) in order to create an unaffiliated modelling and research group. The Department did not succeed in enforcing this idea although, in contrast to other East-German regions, in and around Dresden the industry (Semiconductor, Microship, Solar, Software, Laser, Measurement, Optoelectronics and many other technologies), in majority small and medium-sized enterprises, has grown up very fast from the late 90's on. Several Fraunhofer-Instituts and Max-Planck-Instituts are based in and near Dresden. However, due to the lack of staff there is no possibility to benefit adequately from this favourable situation for the purpose of mathematical modelling in a wide sense.

Workshops on "Industrial Mathematics" for all ECMI (and interested non-ECMI) universities should be organized within a 3-4 years interval by following a series of the conferences, which were held in Lambrecht, Strobl (in the 1992-2000), Dresden (2003, 2009) and Tartu (2013), where the structure and implementation of the programme, problems, corrections, changes, updating and revisions should be discussed.

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