3.5 HEIG-VD (Switzerland)

3.5.1 Swiss micro- and nanotechnology context

In the field of micro- and nanotechnology, Switzerland has always been playing an innovative role, driven by its traditional industrial sectors using fine mechanics, as e.g. watch industry or haute horology, as well as by its Universities, Universities of Applied Sciences (UAS), and Federal Institutes of Technology (ETHZ, EPFL), and research institutes. Examples of current Swiss activities in nanoscience and nanotechnologies can e.g. be found in the Swiss Nanotech Report 2010 [1].

The scientific breakthrough marking also the emerging of nanotechnology had been the invention and development of scanning probe microscopy (SPM) methods at IBM Rüschlikon in the early 1980ies, allowing for the characterisation of surface structures with a lateral resolution at the nanometer and even atomic scale.

The invention of scanning tunnelling microscopy (STM) has been awarded already in 1986 with the Nobel Prize in physics. The similar but more versatile method of atomic force microscopy (AFM) is nowadays also used for the study of samples of industrial relevance.

We use both methods regularly at the Institute of Micro & Nano Technics, Laboratory of Applied NanoSciences (MNT-LANS), at the HEIG-VD (Haute École d'Ingénierie et de Gestion du Canton de Vaud, University of Applied Sciences of Western Switzerland, www.heig-vd.ch), within R&D projects, for industrial service measurements or in the context of laboratory training and further education.

In order to meet the needs of further education in the field of micro- and nanotechnology for engineers of Swiss SME and/or Swiss UAS, a consortium of the Swiss UAS professors active in the field of nanotechnology had developed together with several scientist from Swiss Federal Research Institutes in 2003-2005 a federally recognised postgraduate study programme, the Swiss Master of Advanced Studies in Nano & Micro Technology [2], under financial support by the Swiss Commission for Technology and Innovation (CTI).

The Swiss MAS NMT consortium of professors has been maintained and runs the developed postgraduate study programme for engineers working in industry or in R&D (e.g. at a Swiss UAS) since 2005 as a collaborative project.

The HEIG-VD has actively contributed to this consortium from the early beginning and is implicated in the continuous mutual knowledge transfer within the network.

3.5.2 Method “exploration task”

The objective in the context of the European project ComEd was to further stimulate and enhance the bilateral, or even trilateral, knowledge transfer in the field of micro- and nanotechnology between small and medium size enterprises (SME), UAS and professional training centres or vocational schools via the development and pilot tests of so called exploration tasks.

For this purpose, various models for the implementation of exploration tasks have been developed, tested and evaluated during the pilot project ComEd in view of their applicability for an enhanced bilateral knowledge transfer between UAS and professional training centres / vocational schools on one hand and between UAS and SMEs on the other.

We present and discuss in the following our methodological approaches, experiences and results from the ComEd pilot project in Switzerland.

The following main approaches have been chosen in order to test and implement the method of exploration tasks in the profession oriented training and further education in micro- and nanotechnology at the HEIG-VD:

- Presentation & guided visits of an R&D laboratory at HEIG-VD (Institute of Micro & Nano Technics MNT, Laboratory of Applied NanoSciences (MNT-LANS) and/or Laboratory of Integrated MicroElectronics (MNT-LEMI)) based on exploration tasks for students and training course participants, as well as for visiting apprentices, teachers, and trainers with demonstration of experimental equipment and discussion of industrial applications,
- Visit of a professional exhibition on microtechniques (EPMT/EPHJ) with master students didactically prepared and accompanied by exploration tasks,
- Individual student project work on specific industrial application topics with literature search (master level), students may also bring in nanotechnology application topics proposed by their own industrial contacts,
- Guest lectures from industrials within courses for students (master level) didactically prepared and accompanied through the method of exploration tasks,
- Training course Applications of Micro & Nanotechnology in haute horology with lecturers from industry and HEIG-VD for teachers and trainers as well as for R&D managers.

The different target groups during the phase of the ComEd pilot project were:

- Participants of the Swiss Master of Advanced Studies in Nano & Micro Technology (Swiss MAS NMT [2]),
- Students of the Master of Science in

Engineering (MSE) programme following the nanotechnology oriented module "Applications de nanotechnologies dans l'ingénierie de systèmes et produits" offered by the MRU-TIN HEIG-VD (Master Research Unit Industrial Technologies at the HEIG-VD),
- Microtechnics students of the Bachelor of Science in Engineering programme (HEIG-VD) following the facultative introduction module on nanotechnology "Miniaturisation & Nouvelles Technologies",
- Apprentices in Electronics and teacher of the vocational training school CPNV (Centre Professionel du Nord Vaudois),
- Chinese delegation of R&D managers and teachers from vocational training centres in the field of material science and watch technology,
- Swiss SMEs related to the micro- and nanotechnology field (materials and microstructured surfaces and applications, microelectronics, measurement instrumentation), a company for material analysis service, companies for measurement instrumentation development and sell, start-up companies, industrial R&D departments for product innovation.

The developed and tested exploration tasks concerned e.g. the following topics:

- Atomic force microscopy (AFM) and applications: topography and roughness analysis,
- Scanning tunnelling microscopy and applications,
- Scanning electron microscopy and applications,
- Nano- and micropositioning by piezoelectric actuators,
- Thin film coatings for corrosion protection,
- Nano- and microstructured surfaces for photovoltaics,
- Nanoparticle-polymer hybrid materials for applications in capacitors,
- Carbon nanotubes as cold cathode electron emitters,
- Nanotechnology applications in haute horology,
- Applications of integrated microelectronic circuits.

3.5.3 Best practices: examples, implementation, skills development, institutionalisation

a) Exploration tasks for apprentices and their teachers of vocational training centres

With apprentices in electronics (from CPNV) the topics “Scanning tunnelling microscopy and applications”, “Nano- and micropositioning by piezoelectric actuators” and “Applications of integrated microelectronic circuits” have been tested successfully. A visit of the institute MNT of the HEIG-VD has been prepared together with the teacher being responsible for the electronics class at the CPNV. The exploration task topic was announced to the apprentices under the title “Voir des atomes” (“Seeing atoms”). The prepared visit was organised at the occasion of an open day of the HEIG-VD for future students, and represented thus one specific part among the general presentations of the bachelor study programme in microtechnics and electronics of the department Industrial Technologies of the HEIG-VD. The global logistics of the open day allowed for group visits of about 20 min presentation and demonstration experiments on the topic “Voir des atomes” (Seeing atoms: “Scanning tunnelling microscopy” and “Nano & micropositioning by piezoelectric actuators”, MNT-LANS, HEIG-VD), and about 15 minutes for examples of applications of microelectronic circuit development “Muscles artificiels” et “Fixation de ski améliorée” (“Artificial muscles” and “Improved ski binding”, MNT-LEMI, HEIG-VD).

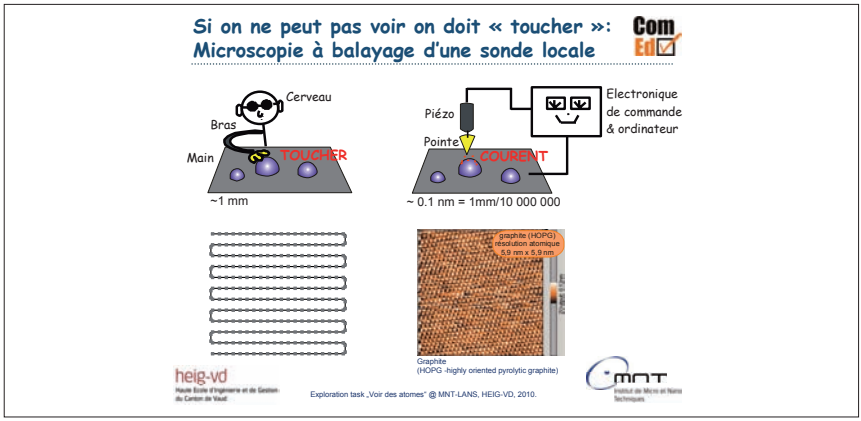


Illustration of the working principle of a scanning tunnelling microscope

Short introductory Power Point presentations with video animations as well as experimental laboratory demonstrations were explained by young engineers, themselves former bachelor students in electronics, electrotechnics or microtechnics of the HEIG-VD, now working at R&D projects of the institute MNT, and partially also active as assistant trainers in laboratory courses for bachelor courses or further education courses in micro- and nanotechnology.

By this approach skills development and knowledge transfer was targeted at both levels: apprentices and trainers (teacher, as well as young engineers). The teacher could discuss the topics with his class before and after the visit. The apprentices of his group showed a particular high interest in the topics and asked significantly more questions during the visit than other groups of apprentices. This form of exploration tasks shall therefore regularly be offered to interested teachers of the CPNV for their classes. Additionally, small group exploration tasks (for 2-3 apprentices) including experimental work in the laboratory or the development of electronic circuits for basic micro technique experiments (e.g. with piezoelectric actuators) by apprentices of the CPNV may be envisaged within a cooperative project.

b) Exploration tasks with students at the master level

With students at the master level, the following different approaches turned out to be successful routes for the implementation of exploration tasks.

(i) Exploration tasks on applications of nanotechnology for the training of skills for literature search, critical reading and writing of scientific articles and technical documents, as well as for the training of presentation skills for R&D engineers:

In the MSE module "Applications de nanotechnologies dans l'ingénierie de systèmes et produits (ANATE)", the exploration task concept was implemented as follows: students have to study an application topic of nanotechnology and shall learn to perform a systematic search of related literature, critically extract the essential information, write a mini-review and present the results in a seminar and by a poster presentation. The students receive a general introduction on nanotechnology as well as on the methodology for their exploration task and are coached by the professor for their personal work.

Part of the participants were involved in R&D projects at the institutes and master research units of the different UAS in Western Switzerland and have chosen a topic of nanotechnology applications related to their field of R&D interest. Some

students also used their personal contacts with SMEs for defining a nanotechnology application topic to explore in relation to the SME activities. The explored subjects in the pilot project concerned e.g. surface microstructures for photovoltaic applications, local adhesion force measurements for the improvement of polymer mould surfaces, technological progress and perspectives for ophthalmologic implants and technological perspectives of nanoparticle-polymer hybrid materials for the application in electric capacitors.

By this approach skills development and knowledge transfer was targeted at several levels, students, professor of the course, professors of the master research units of different UAS and/or industrial partners. Ideally, the majority of the students has already followed an introductory course on nanotechnology and the most commonly used analysis methods, material sciences, solid state physics or chemistry, which strongly increases the degree of understanding of articles from scientific or technical journals as well as the student´s ability to actively contribute to critical and fruitful discussions on the topics explored by their colleagues. The knowledge of English is obviously necessary, too.

A group size of 10 motivated students turned out to be well adapted for this model of exploration task implementation, and allowed for stimulating and fruitful discussions and knowledge transfer on recent technological developments in the field of nanotechnology applications between the students, the professor of the course and professors from R&D institutes within the Swiss UAS network in Western Switzerland. The SMEs or professors having proposed a subject to an individual course participant receive the results report from the student and can thus take benefit from the results report (mini-review article) about a specific application topic of nanotechnology as elaborated and summarised by the student as a pre-study for updating their own knowledge for training, teaching or R&D activities on the topic.

In conclusion, this form of exploration tasks has successfully been implemented in the course offer for MSE students at the master research unit Industrial Technologies (MRU-TIN) at the HEIG-VD; the course “Applications de nanotechnologies dans l‘ingénierie de systèmes et produits (ANATE)” currently runs successfully for the second time with a new group of master students.

(ii) Exploration tasks on industrial applications of micro- and nanotechnology based on a visit of a professional exhibition on microtechniques:

As a further approach to implement exploration tasks for students at the master level, participants of the MSE course "Applications de nanotechnologies dans l'ingénierie de systèmes et produits (ANATE)" as well as some students of the Swiss MAS NMT [2] were invited to visit a professional exhibition on microtechniques (EPMT/EPHT) with exploration task topics related to "Thin film coating applications and characterisation" and "Microstructure laser machining for watch technology".

A conference about microstructure laser machining for watch technology taking place at the exhibition centre was suggested as a starting point. The date of this exhibition at the very end of the spring semester 2010 did unfortunately neither allow a discussion with the whole group of students upon the visit, nor to formalise those exploration tasks as part of the evaluation of the students work. However, the individual feedback collected from several students leads to the conclusion that the method of exploration task was generally judged as helpful for the visit of the professional exhibition, stimulating their curiosity and facilitating them also to speak with some of the exhibiting SMEs.

This form of exploration tasks may thus be developed further and implemented in MSE or MAS courses on micro- and nanotechnology, depending on the compatibility of the dates of the yearly exhibition EPMT/EPHJ and the courses.

(iii) Exploration tasks on industrial applications and instrumentation for micro- and nanotechnology applications based on guest lectures by industrial partners (SMEs):

Within courses of the Swiss MAS NMT [2], guest lectures (technical presentations of 45 min) were given by invited Swiss SMEs. The topics of Nano- and Micropositioning as well as Scanning Probe Microscopy Instruments were addressed by exploration tasks in relation to the invited lectures, stimulating a fruitful discussion of the course participants with the invited R&D engineers of the SMEs and with the organising professor.

The course participants were prepared in advance with the theoretical background of the physical principles and measurement methods of the presented applications and products by conventional methods like classroom teaching, self-organised learning (SOL) [3], exercises and laboratory training.

Laboratory training on scanning tunnelling microscopy and nano- and micropositioning prior to the exploration tasks and guest lectures from Swiss SME: piezoelectric actuation, sample and tip preparation, STM measurements, data analysis.

Two main boundary conditions turned out to clearly favour the bilateral knowledge transfer between UAS and SME in this approach:

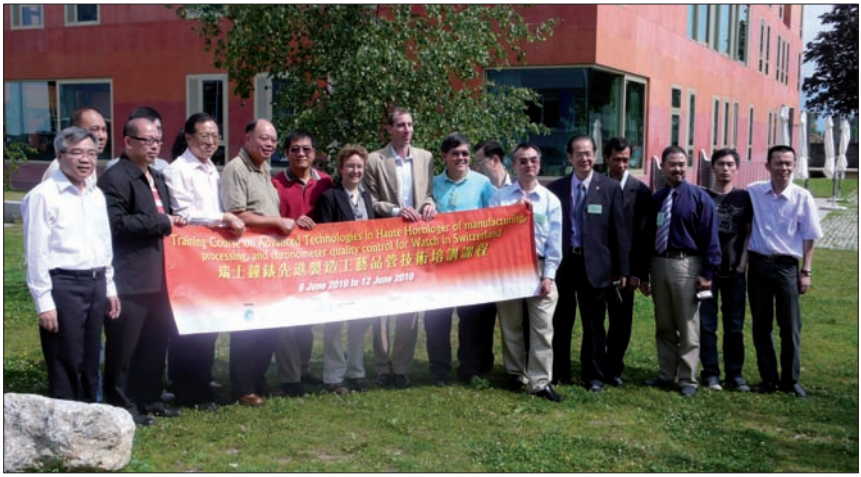
(i) the fact that most participants of the Swiss MAS NMT [2] are partially working themselves as engineers in a company or in an R&D laboratory significantly stimulates the discussion;

(ii) a visit of the R&D laboratory and the training facilities (Institute MNT, HEIG-VD) and/or a business lunch after the lecture give further occasion for a fruitful discussion between the UAS professor (host) and the guest from the Swiss SME.

In summary, this concept has successfully been tested at the further education level (master of advanced studies) and is therefore highly recommended within the Swiss MAS NMT network [2] in order to benefit from a bilateral knowledge transfer between UAS and Swiss SMEs by a regular implementation of exploration tasks in various courses of the postgraduate study programme [2].

c) Exploration tasks for R&D managers and trainers of further education centres: dissemination of the method beyond Europe

Exploration tasks on the topic of Scanning Probe Microscopy for advanced control in manufacturing have been experienced within a training course held at the HEIG-VD for a Chinese delegation of R&D managers and teachers of vocational training and further education centres. For this public, an exploration task similar to the one developed for the apprentices of the CPNV has been applied, i.e. based on the example of a visit of the laboratory MNT-LANS at HEIG-VD. Furthermore examples of the other tested approaches for implementing exploration tasks into vocational training and higher education have been explained to the trainers for their potential application in China and stimulated interest as well as interesting discussions about the cultural differences in learning and teaching methods.



Group of R&D managers and teachers of vocational training centres from the HKPC Swiss training mission at the HEIG-VD for MNT training on micro- and nanotechnology applications in haute horology and watch technology, June 2010.

In an informal way, some of the presented exploration tasks have also been experienced and tested successfully by the partners of the ComEd consortium during the final project meeting in Switzerland in September 2010. During this meeting, a conference with presentations of the ComEd consortium and a visit of the CPNV was organised together with the CPNV and allowed for the dissemination of the project results and fruitful discussions on micro- and nanotechnology applications in vo-

cational and higher education, as well as on the expected benefit of the method of exploration tasks in the context of mobility projects. For the dissemination towards Swiss SMEs a project poster had been exposed at the open day of the Center for Technology Transfer of the HEIG-VD.

In summary, the different approaches have demonstrated the successful implementation of exploration tasks for various target groups in the field of nanotechnology. Combined with other didactical methods, the developed and tested exploration tasks provide a useful tool favouring a bilateral knowledge transfer between UAS and SME, within the UAS networks, as well as between UAS and professional training centres or vocational schools.

Based on the positive experiences from the pilot project, further implementation of exploration tasks with SMEs is foreseen within the courses of the Swiss MAS NMT. Further beneficial impact is expected when applying the method within mobility projects in further education and/or vocational training.

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