European Doctoral Training Support in Micro/Nano-electronics

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Final overview of the expected competencies of future nano-electronics engineers

Deliverable D1.2 - Report

Work Package 1 – Study of future training needs in micro/nano-electronics

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Abstract :

In this Deliverable an overview is generated of the expected competencies and skills required from future PhD students, based on a survey in academia and industry.

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1. Workpackage objectives

The Support Action project 257051, EURO-DOTS, aims primarily at improving the offering and the quality of training provided to European PhD students. It helps fulfilling the requirements for ECTS credits imposed to PhD students by major European universities for obtaining the Doctoral (PhD) degree in Engineering. To this end, a virtual EURO-DOTS platform is created in this project that offers to European PhD students the opportunity to collect ECTS credits throughout Europe from a set of advanced courses in micro/nano-electronics that meet the EURO-DOTS criteria (including high quality and some organisational criteria such as intensive one-week course modules with exam).

In the coming decade there is significant progress but also significant changes predicted in the semiconductor technology, as described in Roadmaps like ITRS. These extrapolate silicon CMOS scaling until (and even below) the 10nm technology node (More Moore), but they also extend the technology developments to the use of totally different devices (Beyond CMOS) in combination and integrated with CMOS (More than Moore). These evolutions may have a large impact on the industry, but also on the knowledge and skills requested from PhD students graduating in the future. The needs and expectations from industry (large companies as well as SMEs) may therefore become significantly different from what is known and done today.

Therefore, the primary objective of this workpackage 1 (WP1) is to analyse the industrial E&T (Education & Training) needs, addressing both large and small companies, today and in the future (the timeframe that we envisage is the next 10-15 years), related to the (interdisciplinary) competencies and skills required from PhD students in the future in both the More Moore, More than Moore and Beyond CMOS domains. In addition, engineers already working in industry may also need to update or extend their compentencies and skills towards these new evolutions. WP1 will therefore also analyse the needs in industry in terms of continuous education of the existing engineers. It is clear that in all of this the collaboration between universities and industry will become increasingly important and essential, not only from the research point of view but also regarding education and training as well as providing/getting access to expensive infrastructure.

The detailed issues that will be considered in this WP1 study and analysis therefore include:

- towards young PhD graduates: identification and specification of specific topics and competencies/skills that are missing and/or emerging and that are weakly addressed by present university education;
- also the need for beyond-technical education such as entrepreneurship, will be investigated, in order to stimulate new economic activities in the nano-electronics area;
- sufficiency of the number of young graduates and how to enhance in-flow;
- the experience of industry (large companies and SME's) with collaboration with local or European universities and their possible involvement in the definition of educational matters at local universities, more in particular in the definition and selection of course modules that can serve young starters but also provide continuous education of employees;

- towards professional employees : need for continuous education (with emphasis not only on content, but also on approach, diversity, interdisciplinary aspects, managerial issues, and so on) including possible involvement of industry in the teaching, its experience with non-traditional educational formats and the value (complementarity) of continuous education E&T programs offered by research centers or by the own E&T services;
- checking the willingness of industry to make infrastructure accessible for advanced E&T needs.

2. Approach

In order to achieve the above objectives and get the view from industry, the following approach was decided by the project partners at the first consortium meeting in Leuven. A first questionnaire had been developed and sent to selected persons in industry. The results provided a first analysis of the needs in industry, and were described in deliverable D1.1.

The conclusions that could be drawn from these responses were :

- Above all industry seems to have a clear need that graduating PhD students are able to design in today's advanced technologies and with state of the art EDA tools.
- Most answers seem to be directed towards a rather shorter-term view inspired by the needs of the companies, instead of a long-term view. This limits the general value of the survey.
- No questions were contained in this survey related to the aspects of continuous education or the collaboration between industry and academia.

Due to the limited set of responses to this first questionnaire, and due to the quite general character of the answers received, it was decided by the consortium at the Stockholm meeting to issue a second questionnaire with more specific targeted questions, and to distribute this questionnaire to a broader set of people and databases. Two versions of the questionnaire have been completed in April 2011, one for academics and one for industry – see the annex. These questionnaires have been distributed to a large group of selected contacts from the databases of Europractice and K.U.Leuven-ESAT-MICAS in the course of early May. In addition, the assistance of the members of the Scientific Committee has been called upon to gather responses. The results of this second questionnaire (both from industry and academic persons) are summarized in this report D1.2.

3. Analysis of results of the second questionnaire

The results of the second questionnaire (both from industry and academic persons) will be summarized below. See annex 1 and 1 bis for the actual questionnaires. All answers are summarized anonymously as promised in the questionnaire, but almost all companies and all professors who answered are active in electronics design. In the case of open-ended questions, similar answers are grouped and ordered according to occurrence.

A large number of 26 responses have been received this time, split evenly among industry and academia: 13 responses from industry, 13 responses from academia. A total number of 26 responses can be considered to be representative for the electronics field in Europe.

The geographical spread of the responses is also quite good with the following responses: Belgium 6, France 2, Germany 2, Greece 1, Italy 5, Ireland 2, Japan 1, Netherlands 2, Norway 1, Poland 1, Sweden 2, United Kingdom 1.

The results are now described in more detail, grouped by the questions asked, and grouped by industrial (see annex 1) and academic answers (see annex 1bis). The detailed results from the industrial feedback have been presented at the EURO-DOTS workshop at ESSCIRC 2011 in Helsinki (see annex 2). The overall results and interpretation have been discussed at the EURO-DOTS project meeting in Bratislava (see annex 3).

3.1. The industrial view

1. Experience of industry in collaborating with local/non-local universities and their possible role and involvement in educational matters
    a. Have you or one of your colleagues been involved or solicited to participate in advisory boards on micro/nanoelectronics educational programs of local or non-local universities?
    YES : 10
        - K.U.Leuven, ENSEIR Bordeaux
        - FH Villach
        - Advisory Committee Microelectronics MSc program
        - Likely
        - University of Parma, Doctorate School of Politecnico di Milano
        - Involved in Leuven, Delft, Eindhoven and Twente
        - Lund University and IMEC
        - I believe someone from my company is on the board
        - Course name : Design of electronic integrated circuits and systems
        - Participation in the educational part of the French “Nano-Innov” plan. See www.cnfm.fr/VersionFrancaise/animations/puce_a.../Puce34Final.pdf

    NO : 3
        - Not to my knowledge

    b. Would you or your colleagues be in favor of such an involvement and willing to participate?
    YES : 11
        - This helps us to have well educated students on future hot topics.

- My intention would be to make MSc/PhD students aware of what is done in industry and how, as opposed to fundamental research
- Yes, but limited time per year
- Some of my colleagues are in advisory boards of other universities
- We will do so on relevant universities
- If that can be to our mutual benefits
- At least for local universities where we recruit
- To help in the definition of content

NO : 2

- Depends on when and where.
- I will have no time to participate, but believe some colleague is already participating

c. Are the programs of the MSc/PhD curricula on micro/nanoelectronics at the universities from which you usually recruit your employees considered fit/adequate to the required skills and knowledge needed in your company? What, if any, extra training do they need with respect to :

i. Technical content and quality of the courses

- mm-wave, analog-RF: few European universities have high-level courses in this topic (due to silicon cost)
- technical content and quality of courses is fine. The basic knowledge is certainly well transferred. Courses lack a part on how microelectronics is handled in the real world, and how it affects design choices
- more hours on microelectronics
- adequate
- basic high-voltage IC design techniques – high-voltage devices
- can always be more competitive
- technical content and quality is normally adequate, even if it should be complemented by more notions on the real state-of-the-art
- for NL : less quality in some fields
- This is hard to answer in a general way. I think all the people our company hires are technically competent in their own field. Often they are specialists and sometimes they lack knowledge outside their own fields, sometimes also general/basic knowledge. For our company, it would be useful if everybody had a notion of the operation of CMOS, CMOS processing and the issues of CMOS scaling
- Technical content and quality of the courses generally no, they mostly require job and location specific introductions

- Very good
- More expertise in system design and system complexity

ii. Hands-on training component
- Evaluation without computer
- Sufficient
- More hours
- Adequate
- OK
- Normally should be improved. Only a few students have the opportunity for making stages in the industry
- Experimental quality drops
- Also hard to answer in a general way. In general, fresh MSc applicants do not have much hands-on experience. For our company, notions of clean room operation, physical and electric characterization would be of use.
- No
- Very good
- Practical skills of combining electronic and microelectronic technologies
- More hardware and embedded software codesign practice

iii. Multidisciplinary approach
- Market analysis and prospective is one of the success keys in new product development, engineers have poor knowledge in such domain
- No perspective on how industry performs designs and why
- Adequate
- OK, maybe more physics
- It is a sensitive item, because it could create people who know something of everything, but are not expert enough in any field. I would favor a broad basis of basic knowledge rather than a little of everything.
- Good.
- This is for our company not all that important. Most people we hire are specialist in their field. Of course, the skills to communicate efficiently with people with other skills are very important.
- No
- Probably too much design oriented
- Designing and programming of embedded systems

- More expertise in hardware and embedded software codesign

iv. Non-technical and managerial aspects
    - English level of "Latin" area schools and universities is generally not enough to have fluent discussions
    - Could be improved. Courses on project management, quality, design for production… would be recommendable.
    - Limited
    - Project/risk management (preparing for the role you often roll into fast when you have a PhD)
    - OK
    - Some managerial aspect is important, also for industry. It would be very important if we would like to prepare students to start an independent activity.
    - Good.
    - This is an important aspect of working in a company. Writing of reports, presenting skills, working with external partners, a certain level of project management is extremely useful and is often missing with fresh PhDs
    - No
    - Not sure

d. Do you know about graduate (PhD) courses on micro/nanoelectronics at PhD level responding to your needs at local/non-local universities?
    - In France : Bordeaux, Lille; in Europe : Twente, Leuven, Lausanne, Pavia – I don't know universities answering to all needs
    - MEAD courses are quite good
    - There is no course on e.g. 6-sigma design, corner variations, rough environments
    - Not very much
    - No
    - In general the curricula at the University of Pavia and Politecnico of Milano from which we take the majority of new hires, is adequate
    - Not at local universities except MEAD
    - E.g. IMEC and DIMES offer such courses. One that springs to mind is the class on carrier transport by Wim Magnus.
    - Yes
    - IDESA: Advanced digital physical implementation flow
    - No

2. Identification of specific topics and of competences/skills that – to your opinion – are too weakly addressed in PhD programs today
    a. What would be the foremost 3 technical topics lacking in today's PhD programs that you would suggest for extra PhD courses ?
        i. Wide technical knowledge : e.g. system, process and modeling for designers
        ii. Wide market knowledge: market analysis, societal analysis…
        iii. Design for high robustness (6 sigma, corner variations, rough environments)
        iv. Design for testability (in a production environment with automated testers)
        v. Robust design
        vi. Power electronics
        vii. Basic high-voltage IC design techniques
        viii. High-voltage devices
        ix. Basic elements of biology
        x. Statistics
        xi. Fundamental physics
        xii. Broad knowledge of electronics (not just the subject of the thesis)
        xiii. Math skills, like statistics
        xiv. CMOS operation, CMOS scaling (advanced)
        xv. CMOS processing: MBE, CVD, ALD, etch, litho…
        xvi. Characterization techniques: RBS, SIMS, TEM
        xvii. No opinion
        xviii. Technology, processes to build devices
        xix. Advanced microprocessor architectures
        xx. Low-power techniques of IC design
        xxi. Hardware and embedded software codesign
        xxii. Statistical modeling and simulation methodology
        xxiii. Safe state machine (hardware and software) design, formal proof

    b. What would be the foremost 3 skills/competences/hands-on practices lacking in today's PhD programs that you would suggest for extra PhD courses ?
        i. How to work without a computer, to have his own idea of a result !
        ii. How to make notes, in order to have re-usable results!
        iii. English for Latin-area universities
        iv. Product-grade design
        v. Robust design
        vi. Power electronics
        vii. Equipment-related aspects
        viii. System aspects – Device manufacturing
        ix. Business aspects of starting up new companies

x. Project/risk management (preparing for the role you often role into fast when you have a PhD)
xi. Team working
xii. Reporting of project results
xiii. Broad knowledge of electronics (not just the subject of the thesis)
xiv. Math skills, like statistics
xv. Experimental skills
xvi. Electrical characterization
xvii. Essentials of process and device simulation
xviii. Some clean-room experience
xix. Basics of IP generation – how to recognize a patentable idea, how to write it down, how to deal with a patent search, etc.
xx. No opinion
xxi. Hands-on characterization of devices
xxii. Multidisciplinary projects

c. Would you consider the treatment of issues such as market/economic aspects, managerial aspects, business aspects, manufacturability aspects, legal aspects, etc. a must (20% or more of the PhD course program) or marginal (<5%) ?
- 30% : When we begin a project we must know why we make such project, and how "to sell" it to the management, the public authorities in order to have money to make it
- 10% : It is important, but not the primary goal of a PhD. But having this knowledge will prepare PhD students better for future jobs.
- 15%
- 10% : More detailed training can be provided within companies
- 20% definitely
- 10% : cost aspects of results/products, competition, patents…
- 10%
- 10%
- 10% : all these things are very useful as long as they are generic; marketing, business, legal, etc. are all very company dependent
- 10% : a mix of this is good, the individual can choose
- 10-20% : Legal aspects (IP) are key in this industry. Being able to work in a team is also important. Finally negotiation skills are also important.
- 10% maximum

d. What would be non-technical aspects or specific skills that you would prefer seeing treated more in PhD programs ?
i. Wide market knowledge: market analysis, societal analysis

ii. Some form of project management (scheduling, timing and budgeting of projects)
iii. Communication skills (presentation + meeting / communication / team rules, de-escalation, how to communicate to a customer, etc).
iv. Some education on cultural aspects (Japan, China, USA, etc.)
v. Business aspects of setting up new companies
vi. Project/risk management (preparing for the role you often roll into fast when you have a PhD)
vii. Project planning
viii. Economic aspects of technology development
ix. Some general knowledge of business and finance
x. Multi-cultural management
xi. Scientific English writing; reporting
xii. Crisp and clear presentation skills
xiii. Presentation techniques
xiv. Project management
xv. IP
xvi. No

e. Would you recommend education/training providers to also organize (nanoelectronics specific) entrepreneurial oriented courses (not the traditional courses from business schools) ?
YES : 8
- They already exist to some extent in Lund
- We need more startups in Europe

NO : 3
- MBA is conceived for that.

No opinion : 2

f. Would you be prepared to also contribute to such beyond-technical courses by providing lecturers ?
YES : 8
- but that is not simple
- I could contribute

NO : 4
- that would depend – for our specific company that may be hard to commit to

No opinion : 1

3. <u>Need for continuous education of industry workers - with attention not only to the content but also to format, multidisciplinary aspects, inclusion of managerial issues, and so on</u>

a. Do you call on or interact/collaborate with local/non-local universities for ensuring continuous education of your employees?
   YES : 6
   - ref EMC
   - restarting
   - we support the local university
   - Warsaw University of Technology – Institute of Microelectronics and Optoelectronics

   NO : 7
   - There are some service providers like EuroTraining, Chalmers, side events on conferences…
   - Very little
   - Such education is not yet active/effective in our area (south of France)

b. If such courses would be available through a European platform (e.g. EURO-DOTS PhD courses with focus on industry-relevant topics, content and format), would you consider sending your engineers to such courses?
   YES : 9
   - depending on the content
   - depends on price
   - a few of them

   NO : 3
   - time is very expensive ; this would probably only be considered if the course is exactly suiting certain of our needs.
   - Occasionally, but the local setup is more attractive from a logistics point of view

   No opinion : 1

c. Do you consider the existence of the EURO-DOTS platform with its intended broad spectrum of selected advanced PhD courses that target to fulfill specific industrial needs (ensured by the steering of the Scientific Committee mostly composed of industrial experts) as : (please select one)
   i. Of no value for your company
   ii. Nice to have : 4
   iii. An interesting opportunity : 7
   iv. A major added-value for your company : 1
   v. No opinion : 1

d. Where would you see the major response to your continuous education needs from such an interaction ? (please select one)
   i. Pure technical training : 1

ii. Combination of technical and non-technical training : 9
iii. Interaction with colleagues from universities and other companies : 2
iv. No opinion : 1

4. Willingness of industry to be also directly involved and to contribute to such programs in close collaboration with their academic colleagues
   a. Do you consider involving also lecturers from industry in such EURO-DOTS courses as :
      i. Optional (if good industry lecturers are available) : 7
      ii. Necessary : 6

   b. Would you be willing to contribute to such courses ?
      i. To treat technical issues :
         YES : 8
         - mm-wave, analog-RF
         - should be done by someone who is still doing product-grade designs
         - I myself would be willing to give e.g. a specific lecture of interest, if my company would fully support me in this role and time is available to do it decently (not just reusing material of person y)
         - Yes, at limited hours per year
         - A/D mismatch etc
         - But only when workload permits (i.e. no)
         - If there is a fit

         NO : 2
         - depends on the circumstances
         - ideally yes, but currently no time

         No opinion : 3

      ii. To treat issues related to business, manufacturability, etc :
         YES : 6
         - Especially on issues like technology roadmapping
         - In principle
         - But only when workload permits (i.e. no)

         NO : 6
         - I am not a specialist of these fields
         - Ideally yes, but currently no time
         - Not easy to identify people
         - Not the expertise of our location

         No opinion : 2

- Willingness is one thing, however I think this is something which is hard to commit to.

c. Would your organization be prepared to open its facilities to PhD students as part of a hands-on component in a course?

YES : 8

- Depends on what is required. Hands-on technical sessions at our company will be impossible since all computer/licences are occupied for commercial work. Demonstrations of how ICs are tested and produced in volume are certainly interesting for PhD students, but not available in our company.
- Maybe yes, but would have to be negotiated
- Limited, but possible for suitable specific and company relevant project work, and after all instructions/safety/etc are ensured
- We routinely have PhD students from nearby universities, and we participated in the Marie-Curie program
- Possibly
- In principle we are open to talented interns
- To some extent, we already have thesis workers at our premises and offer summer jobs.

NO : 5

- Except for PhD students hired by the company
- We do have several MSc and PhD students working in-house on technological and scientific topics related to the thin-film deposition processes and equipment. We are too small to accommodate a group of PhD students for a hands-on internal training
- Probably not… but maybe in the frame of a company visit to production facilities if it is relevant for a course
- Not sure
- Locally we are not currently organized for such activities

Conclusions from industry view

The following conclusions can be drawn from the feedback from industry to the second questionnaire :

- industry is willing to be involved with education in universities through curricula/advisory boards.
- industry is overall satisfied with the quality of MSc and PhD students, but they identified several subjects that would need better coverage in existing programs

  - technical, non-technical and managerial, skills & competences.

- industry needs continuous education and is to some extent willing to participate to training programs such as EURO-DOTS for that reason.
- some companies are willing to make its infrastructure available to PhD students under specific conditions.

The above results will now be compared to the view from academia below, and the overall view will be used to define the ultimate training needs and compare them to the current course offerings in Europe, possibly leading to issuing specific calls for course proposals on specific subjects not covered today.

3.2. The academic view

1. Experience of academia with incoming Master students

   a. Are the programs of the MSc curricula on micro/nanoelectronics at the universities from which you usually recruit Master students for your PhD program considered fit/adequate to the required skills and knowledge needed as part of your PhD program? What, if any, extra training do these students typically need during the PhD program with respect to:

      i. Technical content and quality of the courses.

      - The contents of MSc fit well the needs of the PhD program.
      - The lacks I have observed are mostly at the fundamental level, insufficient experience with mathematical and/or physical analysis, lack of good physical feeling, lack of experience with system design.
      - Knowledge of semiconductor physics and advanced device behavior and modeling is usually weak.
      - OK for local univ but not always for international students who did their master elsewhere – sometimes they still lack basics in electronics although on paper they studied everything.
      - We can recruit from many disciplines, so some “leveling” technique is required. Computer programming skills seem lower than in the recent past and there are indications that device-level training and science backgrounds are not at the level required for interdisciplinary research projects.
      - Discrete math, numerical methods, statistics
      - RF circuits

- Fundamental knowledge of electromagnetism, electronic circuit design, device physics, industrial mathematics, signal processing, electrical experiment and measurement, etc. These are already studied on the bachelor course; however, conventional PhD students should study again to obtain deep understanding.
- In general they fit.
- Adequate, but is typically improved during PhD courses.

ii. Hands-on training component

- This is the weakest part; hands-on training in experimental characterization and fabrication would be needed.
- Often pretty adequate, except maybe in the use of advanced design tools.
- Numerical simulation and characterization of semiconductor devices usually missing.
- Not many are capable of doing own measurements.
- As mentioned, computer programming, and in addition technical writing.
- Use of advanced measuring equipment, Matlab, Simulink, Cadence, Xilinx.
- Fair, but is typically improved during PhD courses.

iii. Multidisciplinary approach

- No major problems concerning this aspect.
- This is a general problem, also based on the already mentioned lack in fundamental training.
- Many students don't have such a broad education as in Leuven, so they suffer from the multidisciplinary dimension.
- Yes, when required.
- This is typical for many of research topics and requires a broad range of technical and training modules in the first year.
- Adequate.

iv. Non-technical and managerial aspects

- There are no specific requirements on this side.
- This is a more personal question; the abilities of students are very diverse. There is certainly a lack in learning to see possibilities and understanding entrepreneurship techniques.

- Most have little skills in non-technical - speaking and writing English is sometimes difficult – and entrepreneurship is not standard for most countries – cultural differences are sometimes also important to determine the PhD success.
- Yes.
- We are introducing innovation and commercialization modules for PhD candidates, but this is the early phases.
- Patents, technical writing, LaTeX.
- Research management.
- Scarce.

b. Are these extra courses/training provided at your university or available at any other European university you know ? (please be specific)

- Courses on characterization and fabrication are provided at several European universities (e.g. INPG, KTH).
- The two universities I know best (TU Delft and TU Munich) both offer extensive courses in all the aspects mentioned. See e.g. their respective Master's programs in Microelectronics, Electronic System Design and Telecommunication (full MSc programs at a high international standard).
- We provide this; I don't know elsewhere.
- Not really at our university; there are a few technical courses plus some nontechnical courses available for PhD students, but they are not required and often students don't take them.
- No.
- Yes, we now have a means of sharing modules between all Irish universities with automatic credit exchange. Modules are delivered by video conference, web based or on-site training.
- We provide some training in RF circuits but send students out to courses on Matlab, Simulink, Cadence, Xilinx…
- Required knowledge can be obtained basically to take the class on the bachelor course.
- They are provided in my university.

2. <u>Identification of specific topics and of competences/skills that – to your opinion – are too weakly addressed in PhD programs in micro/nanoeletronics today</u>

a. What – if any – would be the foremost 3 technical topics lacking in today's PhD programs that you would suggest for extra courses at PhD level (and where you would send your PhD students to if organized) ?

- Advanced characterization of electron devices.
- Basic CMOS fabrication
- (Advanced) solid-state physics and process technology
- Signal processing and information theory
- Computer architecture and system design
- System-level applications or products opportunities and methods to exploit micro-nano-electronics innovations; how to predict impact, industry or consumer acceptance.
- CAD and design methodology – most designs require sophisticated tools these days but few students know about these.
- Beyond-CMOS devices and potential for future designs.
- Robust design techniques.
- Manufacturability aspects.
- Hands-on fabrication training. Partially done on-site but would benefit with sharing our photonics fabrication training with external microelectronics and microsystems training.
- Wireless circuits and systems – could benefit from broader expertise across Europe.
- Applications of ICT to energy and energy management.
- Numerical methods
- Probability and statistics
- (Mixed) signal processing
- Basic physics and mathematics for EE students
- Testing and design for test.
- Advanced devices.
- Microprocessor design.
- State of the art technology.
- Current tools for analysis and implementation of devices and circuits.
- Economic aspects.

b. What would be the foremost 3 skills/competences/hands-on practices lacking in today's PhD programs that you would suggest for extra PhD courses ?

- Advanced characterization of electron devices.
- Basic CMOS fabrication
- Nanoscale processing technology

- Design of advanced circuits (VLSI, hybrid, HF)
- Multiprocessor system design
- Real hands-on training on advanced processing steps, cleanrooms management, etc.
- Measurement skills.
- Academic writing and speaking.
- How to turn your research into a product or company.
- Technical writing and presentation.
- Developing a business plan.
- Cadence
- Xilinx
- Advanced measurement techniques.
- Measurement skill, knowledge, and experience for analog and RF circuits
- Building behavioral model for EE systems.
- Design mixed analog and digital IC; from system and layout.
- Writing and give talk on technical paper.
- Team management.
- English.
- Designer approach.
- Hands-on technology.
- Opportunity to experience prototypes.

c. Would you consider the treatment of issues such as market/economic aspects, managerial aspects, business aspects, manufacturability aspects, legal aspects, etc. a must (20% or more of the PhD course program) or marginal (<5%) ?

- 20 % (please specify) managerial aspects, manufacturability aspects, legal aspects.
- 20% (please specify) seems about right – high emphasis on entrepreneurial skills, especially in the context of the design of new types of systems.
- 10% (please specify) it is a must (because the overall R&D / industrial context should be presented and exemplified) but 20% seems too large for me since the issues cannot be put in practice during the PhD.
- MUST 20%.
- 10% (please specify) market/economic, managerial, business, manufacturability aspects.
- We are introducing approx. 25% of the structured component of the PhD (this equates to about 7% of the total PhD credits) to these topics. If the PhD candidate opts to increase this to approximately twice this amount (by

earning credits outside of the PhD requirements), he may then earn a level-9 certificate in commercialization and entrepreneurship.
- 5% (please specify) An overview is sufficient.
- 10%.
- 20%.
- A must (= 20% or more).

d. What would be non-technical aspects or specific skills that you would prefer seeing treated more in PhD programs ?

- Managerial aspects
- Manufacturability
- Entrepreneurship
- Quality/reliability/security
- R&D transfer models
- New emerging business models
- Entrepreneurship
- Speaking (presentation skills) and writing incl. reporting
- Technical writing and presentation
- Market/economic/business
- Commercialization of technology
- Cost analysis
- Technical writing (including patents)
- How understand the world, society, nature, systems, materials; some philosophy.
- Managerial aspects.
- Entrepreneurial opportunity in the microelectronics field.

e. Would you recommend education/training providers to also organize (nanoelectronics specific) entrepreneurial oriented courses (not the traditional courses from business schools) ?

- Yes : 8
- No : 2
- Comments :
  - No, except for cases from the field.

f. Would you be willing to organize any of the above missing courses yourself within a European context and therefore make it accessible to other European PhD students ?

- Yes : 5
- No : 6
- If yes, please specify :
  - TU Delft and TU Munich can effectively contribute !
  - K.U.Leuven can open some courses to outside students within a frame like Eurodots.
  - Analog integrated circuit design.
  - Yes, we are working on this with our College of Business and Law, and are making these available nationally. Can be extended to a European audience, specific workshops are being organized annually too.
  - (Mixed) signal processing.
  - No, I have no such talents.
  - Device physics, power devices, electronics.

3. Interaction with industry

a. Does your university provide continuous education programs for industry today that could be offered to a broader range of companies ?

- Yes : 3
- No : 5
- If yes, please specify :
  - Difficult to answer; continous education programs are often pretty specifically designed.
  - Yes, but not on a regular pace for micro/nanoelectronics.
  - Not yet in electronics field.
  - Yes: nanoelectronics to semiconductor manufacturers; microelectronics fabrication to semiconductor manufacturers. Both courses are being given to manufacturers by our staff.
  - Yes, integrated circuit processing technology.

b. Where do you see any needs in terms of continuous education programs for industry that are not available today ?
(please specify)

- I think “System Design” is the biggest need, but must be geared to specific needs.

- Yes, especially on how, when and what for system-level industries might expect to benefit from innovations, evolutions, roadmaps… in micro/nanoelectronics.
- Keep industry updated on novel trends in design.
- Keep industry updated on novel application areas for electronics.
- We are in discussion with our industry partners and tailor these courses to their needs.
- Matlab, Simulink, (mixed) signal processing, numerical methods.
- I have a training course for industrial analog IC designers in the industrial consortium, not in university.

c. Do you involve or would you consider involving lecturers from industry in PhD courses at your university ?

- Yes : 10
- No : 0
- If yes, for what courses :
  - Management.
  - Manufacturability.
  - Yes, as part-time lecturers, in almost all topics.
  - All courses.
  - Yes, as guest speakers for advanced courses.
  - For specific seminars devoted to integrated circuit design.
  - Yes, we do so, mostly in the circuit design area.
  - Yes, data converters, advanced analog IC design
  - Yes, for the program of management courses, such as management of intellectual properties, industrial characterization. The other is practical and advanced RF measuring by Agilent.
  - Manufacturing technology and VLSI systems.

d. Would you take advantage of the possibility offered by companies that would be prepared to open their facilities to PhD students as part of a hands-on component in a course ?

- Yes : 9
- No : 1
- If yes, please specify your needs :
  - Yes, basic CMOS process.
  - Yes, see above.
  - Yes, we would appreciate if companies would open up their infrastructure.

- Yes, fabrication and, then, experimental characterization of designed ICs.
- Yes, access to measurement practice.
- Yes, good example is the practical and advanced RF measuring by Agilent.
- Yes, this is mandatory for an adequate formation of PhD students.

e. Do you have an advisory board with industry representatives for your micro/nanoelectronics educational programs (including the PhD program) ?

- Yes : 6
- No : 4
- Comments :
  - Both the TU Delft and the TU Munich have industry boards in aech MSc discipline covered.
  - We have an advisory board for the overall engineering curriculum, as well as for some specific big research projects, but not specific to micro/nanoelectronics.
  - No, there is a more general board at the level of the engineering faculty.
  - These are currently being established in relation to new national initiatives in graduate education.
  - Yes, we have one for the structured graduate school.
  - Yes, a steering committee composed by professors and industry members which help us to define the educational program and MSc curricula.

Conclusions from academic view

The following conclusions can be drawn from the feedback from industry to the second questionnaire :

- academia sees some need in missing education, both technical, hands-on and non-technical. System view remains a problem. So is experimental skills, process knowledge, English speaking and writing, and business aspects incl. patenting and entrepreneurship.
- several universities are willing to offer courses (or to distribute existing courses on a wider scale).
- few universities provide continuous education for industry, but they all involve industry speakers in their curricula. They would also take advantage of the possibility to use industry infrastructure.

- many universities have an advisory committee, be it not always for micro/nanoelectronics

The above results together with the view from industry will now be used to compare them to the current course offerings in Europe, leading to the gap analysis and finally resulting in issuing specific calls for course proposals on specific subjects not covered today.

4. Conclusions

This deliverable has described the initial report about the education and training needs identified at the level of graduating PhD students in Europe. To this end, two subsequent questionnaires have been developed and distributed to industry and academia. The combined view from industry and academia gives a good view on the PhD-level training needs. Within the EURO-DOTS consortium, these needs will now be compared with the current course offerings in Europe. For any gaps identified in that way, specific calls for course proposals on specific subjects not covered today may be issued by the EURO-DOTS consortium, in order to fill the gaps.

Annex 1 : Second questionnaire to industry

EURO-DOTS QUESTIONAIRE

Academic training needs at PhD level in nanoelectronics

Context

EURO-DOTS (European DOctoral Training Support) is a European project that aims at improving the offering and quality of training proposed to European PhD students. A coherent set of advanced courses in micro/nanoelectronics explicitly accredited by major European universities in the framework of their Doctoral Program will be made easily accessible to European PhD students, offering the opportunity to collect ECTS credits throughout Europe. To identify the missing links in today's course offering in the light of future needs of industry, we would like to survey opinion leaders from academia and industry for their feedback.

Please fill out this questionnaire and mail the completed form to eurodots@esat.kuleuven.be (or fill out by hand and scan it). The **deadline is May 22, 2011**! Please be as specific as possible. The surveys will be treated anonymously. You will receive a final summary.

SURVEY :

1. Experience of industry in collaborating with local/non-local universities and their possible role and involvement in educational matters
    a. Have you or one of your colleagues been involved or solicited to participate in advisory boards on micro/nanoelectronics educational programs of local or non-local universities?
    Y/N (please specify) …….…….
    b. Would you or your colleagues be in favor of such an involvement and willing to participate?
    Y/N (please specify) ……..….

c. Are the programs of the MSc/PhD curricula on micro/nanoelectronics at the universities from which you usually recruit your employees considered fit/adequate to the required skills and knowledge needed in your company? What, if any, extra training do they need with respect to :
   i. Technical content and quality of the courses ……
   ……
   ii. Hands-on training component ……...
   iii. Multidisciplinary approach ……
   iv. Non-technical and managerial aspects ……..
d. Do you know about graduate (PhD) courses on micro/nanoelectronics at PhD level responding to your needs at local/non-local universities?
   ……

2. <u>Identification of specific topics and of competences/skills that – to your opinion – are too weakly addressed in PhD programs today</u>
   a. What would be the foremost 3 technical topics lacking in today's PhD programs that you would suggest for extra PhD courses ?
      i. ……
      ii. ……
      iii. ……
   b. What would be the foremost 3 skills/competences/hands-on practices lacking in today's PhD programs that you would suggest for extra PhD courses ?
      i. ……
      ii. ……
      iii. ……
   c. Would you consider the treatment of issues such as market/economic aspects, managerial aspects, business aspects, manufacturability aspects, legal aspects, etc. a must (20% or more of the PhD course program) or marginal (<5%) ?
      ....… % (please specify) ….……...
   d. What would be non-technical aspects or specific skills that you would prefer seeing treated more in PhD programs ?
      i. ……
      ii. ……
   e. Would you recommend education/training providers to also organize (nanoelectronics specific) entrepreneurial oriented courses (not the traditional courses from business schools) ? Y/N
   f. Would you be prepared to also contribute to such beyond-technical courses by providing lecturers ? Y/N

3. Need for continuous education of industry workers - with attention not only to the content but also to format, multidisciplinary aspects, inclusion of managerial issues, and so on
    a. Do you call on or interact/collaborate with local/non-local universities for ensuring continuous education of your employees?
       Y/N (please specify) …….
    b. If such courses would be available through a European platform (e.g. EURO-DOTS PhD courses with focus on industry-relevant topics, content and format), would you consider sending your engineers to such courses? Y/N
    c. Do you consider the existence of the EURO-DOTS platform with its intended broad spectrum of selected advanced PhD courses that target to fulfill specific industrial needs (ensured by the steering of the Scientific Committee mostly composed of industrial experts) as : (please select one)
        i. Of no value for your company
        ii. Nice to have
        iii. An interesting opportunity
        iv. A major added-value for your company
    d. Where would you see the major response to your continuous education needs from such an interaction ? (please select one)
        i. Pure technical training
        ii. Combination of technical and non-technical training
        iii. Interaction with colleagues from universities and other companies

4. Willingness of industry to be also directly involved and to contribute to such programs in close collaboration with their academic colleagues
    a. Do you consider involving also lecturers from industry in such EURO-DOTS courses as :
        i. Optional (if good industry lecturers are available)
        ii. Necessary
    b. Would you be willing to contribute to such courses ?
        i. To treat technical issues :
           Y/N (please specify) …….
        ii. To treat issues related to business, manufacturability, etc :
           Y/N (please specify) ……
    c. Would your organization be prepared to open its facilities to PhD students as part of a hands-on component in a course?
       Y/N (please specify) …….

Annex 1 bis: Second questionnaire to academia

EURO-DOTS QUESTIONAIRE

Academic training needs at PhD level in nanoelectronics

Context

EURO-DOTS (European DOctoral Training Support) is a European project that aims at improving the offering and quality of training proposed to European PhD students. A coherent set of advanced courses in micro/nanoelectronics explicitly accredited by major European universities in the framework of their Doctoral Program will be made easily accessible to European PhD students, offering the opportunity to collect ECTS credits throughout Europe. To identify the missing links in today's course offering in the light of future needs of industry, we would like to survey opinion leaders from academia and industry for their feedback.

Please fill out this questionnaire and mail the completed form to eurodots@esat.kuleuven.be (or fill out by hand and scan it). The **deadline is May 22, 2011**! Please be as specific as possible. The surveys will be treated anonymously. You will receive a final summary.

SURVEY :

1. Experience of academia with incoming Master students
    a. Are the programs of the MSc curricula on micro/nanoelectronics at the universities from which you usually recruit Master students for your PhD program considered fit/adequate to the required skills and knowledge needed as part of your PhD program? What, if any, extra training do these students typically need during the PhD program with respect to :
        i. Technical content..... ……
        ……
        ii. Hands-on training component ……...
        iii. Multidisciplinary approach ……

iv. Non-technical and managerial aspects ……..

b. Are these extra courses/training provided at your university or available at any other European university you know ? (please be specific)

……

……

2. <u>Identification of specific topics and of competences/skills that – to your opinion – are too weakly addressed in PhD programs in micro/nanoeletronics today</u>

a. What – if any – would be the foremost 3 technical topics lacking in today's PhD programs that you would suggest for extra courses at PhD level (and where you would send your PhD students to if organized) ?

i. ……

ii. ……

iii. ……

b. What would be the foremost 3 skills/competences/hands-on practices lacking in today's PhD programs that you would suggest for extra PhD courses ?

i. ……

ii. ……

iii. ……

c. Would you consider the treatment of issues such as market/economic aspects, managerial aspects, business aspects, manufacturability aspects, legal aspects, etc. a must (20% or more of the PhD course program) or marginal (<5%) ?

....… % (please specify) ….……...

d. What would be non-technical aspects or specific skills that you would prefer seeing treated more in PhD programs ?

i. ……

ii. ……

e. Would you recommend education/training providers to also organize (nanoelectronics specific) entrepreneurial oriented courses (not the traditional courses from business schools) ? Y/N

f. Would you be willing to organize any of the above missing courses yourself within a European context and therefore make it accessible to other European PhD students ?

(please specify) ……

……

……

3. <u>Interaction with industry</u>

a. Does your university provide continuous education programs for industry today that could be offered to a broader range of companies ?

Y/N (please specify) …….

.....

b. Where do you see any needs in terms of continuous education programs for industry that are not available today ?
(please specify) …….....
.....

c. Do you involve or would you consider involving lecturers from industry in PhD courses at your university ? Y/N (for what courses) .....

d. Would you take advantage of the possibility offered by companies that would be prepared to open their facilities to PhD students as part of a hands-on component in a course ?
Y/N (please specify your needs) ……..

e. Do you have an advisory board with industry representatives for your micro/nanoelectronics educational programs (including the PhD program) ? Y/N (please specify) ……..……