Final Activity Report

ENEX Competence Profile

Output 1 / A3

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1. The ENEX rationale

The short-cycle qualification *'ENEX – Expert in Nanotechnology Exploitation'* has been developed for professionals as well as for graduate and postgraduate students facing the rapidly growing importance of nanotechnology in industry, research and the society as a whole.

Nanotechnology (NT) is a strongly emerging area of research and activity, opening up new markets, and leading to new products, processes and services in almost all industrial sectors. As a result, there is an increasing demand of particularly qualified personnel in companies producing and using nanotechnology, but also in research organisations developing new technologies, in consulting firms and other institutions focusing on the nanotechnology research-to-market process.

The *ENEX (Expert in Nanotechnology Exploitation)* is the 'interface' between laboratories and researchers developing nanotechnologies and the industry and health sector using them. He/she is either employed at strategic level (project manager, innovation manager, business development manager etc.) in companies specializing in or using NT, or is working as an innovation or technology transfer professional in the R&D sector or in an intermediary organization.

Due to the multidisciplinary nature of nanotechnology and its wide range of applications, the ENEX must have a sound knowledge and understanding of the underlying NT principles, material properties and processing techniques enabling him/her

- to draft innovative solutions based on NT to industrial product development by choosing the 'right' combination of materials and process techniques to solve a specific technical problem, and
- to steer scientific/ academic research in the field of NT to realistic targets that are application-oriented and market-led.

Particularly concerning the latter, it is clear that the ENEX, apart from technical knowledge, must have further competences to assess and manage the research to market process. He/she should know about the critical phases and bottlenecks of the product innovation process and how to deal with them to take the right decisions at strategic level ('do the right things') as well as operational level ('do things right').

The ENEX training course, therefore, has been designed as an interdisciplinary e-learning platform combining nanotechnology modules with innovation management contents, providing knowledge, skills and competences in particular to key staff of NT companies or related industry, as well as to researchers, intermediaries and other stakeholders of the NT research to market process.

2. The ENEX competence profile

2.1 Target groups

The ENEX training addresses managers in companies, in the science/academic sector or intermediary organisations who want to fill qualification gaps, improve their factual and methodical expertise, check their own professional strengths, and receive a validation of their knowledge, skills and competences based on the EQF and ECVET standards.

It further addresses graduates who want to expand their educational background and acquire additional abilities that are needed to carry out specific tasks at management level in companies, in the science/academic sector or intermediary organisations.

In more detail, the target groups of the ENEX training course are:

- Companies, in particular SMEs, engaging in NT or related industries:
  - executive,
  - project managers,
  - business development managers,
  - innovation managers,
  - other key staff at management level.
- Universities, research and technology centres (RTC), business incubators, technology transfer organisations (TTO), consulting firms:
  - center managers,
  - innovation and technology transfer managers/consultants,
  - network/cluster managers,
  - individual scientists and researchers.
- Post-tertiary graduates in the fields of
  - natural sciences: physics, chemistry, biology,
  - materials science,
  - medicine,
  - engineering sciences: electrical engineering, microsystems technology, mechatronics, etc.
- Other stakeholders:
  - VET providers,
  - high school teachers,
  - political decision makers,
  - regional development agencies,
  - chambers of commerce and industry,
  - industrial associations,
  - capital investors,
  - patent attorneys, etc.

2.2 ENEX key competence areas

The ENEX qualification profile is structured according to the EQF (European Qualifications Framework) and ECVET (European Credit System for Vocational Education and Training) descriptive frame and comprises a set of learning modules relating to key subjects/activities in the process of nanotechnology-based innovation. Following ECVET, learning outcomes are defined for each module on the basis of knowledge, skills and competences (see chapter 3.6).

The key subject areas of the ENEX qualification were investigated by means of a comprehensive study carried out in all ENEX partner regions. The study included

- an online company survey collecting quantitative information on the level of engagement of the main ENEX target groups in nanotechnology and innovation management and on potential qualification needs in these areas (The evaluation report is available as pdf download on the ENEX project website http://www.enex-nano.eu.);
- a qualitative analysis based on in-depth interviews with managers/ experts responsible for managing innovation processes in their respective companies or organizations, to identify key activities of the ENEX and to define theoretical knowledge and practical skills the ENEX should ideally have after completion of the training;
- the feedback from two face-to-face pilot trainings organized in Enschede/NL in January 2016 and in Lodz/PL in March 2016 on selected topics of nanotechnology and innovation management, respectively;
- an accompanying desk research of currently available vocational profiles and education & training offers in the thematic fields addressed in the ENEX project.

2.2.1 Company survey

A total of 157 parties, of which were 97 industrial firms (84 SMEs, 13 large corporations), 48 science organizations and 12 other stakeholders of the nanotechnology research-to-market (R2M) process (consultancies, networks, cluster management bodies), responded to the survey. 71% of the companies involved had already knowledge and experience in nanotechnology, 73% in innovation management.

Major application markets of the responding parties were found to be (see Fig. 1)

- materials,
- health/ medical technology,
- biotechnology,
- environmental technology,
- the chemical & pharmaceutical industry,
- the energy sector.

A larger share of the respondents had already been positioned in these markets or expressed their interest to go there. With regard to nanotechnology applications,

- materials,
- biotechnology & medicine,
- sensors & actuators,
- electronics & photonics

were identified as the primary fields of interest (Fig. 2).

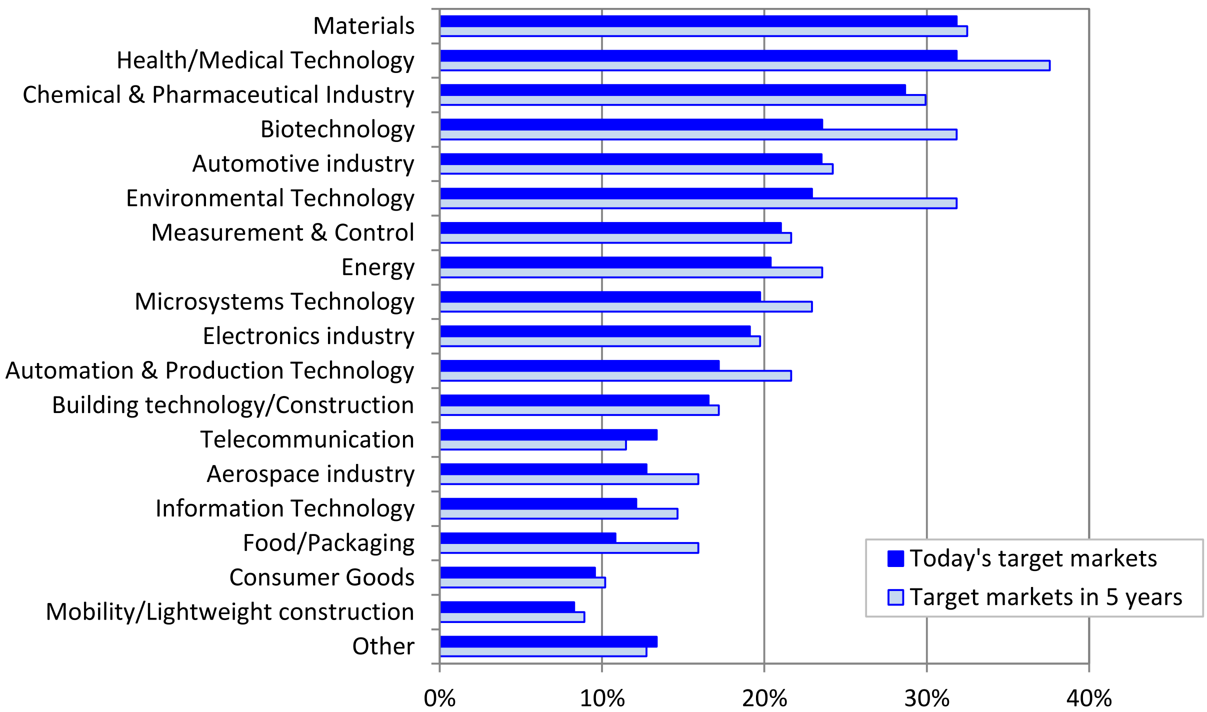

Fig. 1 *Comparison of the most important target markets of today and in 5 years from now based on the responses of the ENEX company survey.*

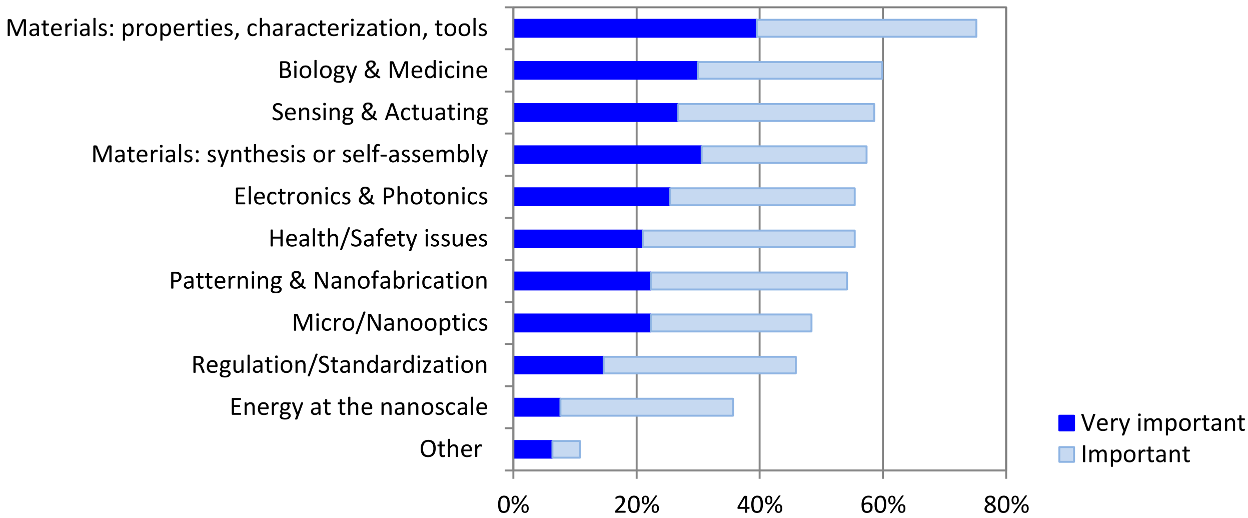

Fig. 2 *Fields of nanotechnology that are of particular interest/importance to the companies involved in the survey*

The most important driving forces of nanotechnology innovation processes in the companies involved were new (nano) technologies and new materials. Concerning materials, the companies had a focus on polymers and metals, ceramics, semiconductors and carbon nanomaterials. Micro/nano analytics, colloidal/supramolecular chemistry and thin film technologies (PVD/CVD) were classified as the dominant (nano) technology processes in the companies.

22% of the companies had used VET offers in nanotechnology, 15% in innovation management, however only 8% had experience with digitalized VET concepts in nanotechnology, even less in innovation management (4%). Almost one quarter of the respondents expressed a demand for further VET in the field of ‚nano' and/or innovation management.

2.2.2 Company interviews

The qualitative method of individual interviews was used to deepen the understanding of existing or emerging company needs in the fields of nanotechnology and innovation management and, in particular, to identify key competencies of the ENEX vocational profile.
5 interviews were carried out per region with experts responsible for managing NT innovation processes in their respective companies or organizations. As could be expected, the information and comments provided by the interviewees varied substantially from company to company, due to the heterogeneity of the target groups and the fact that the specific form of innovation management strongly depends on the individual business model of the company involved.

Nevertheless, the interviews gave valuable insight into the organization and management of NT innovation processes in companies and provided significant input for refining and sharpening the ENEX competence profile. Key findings and recommendations for the ENEX profile were:

- The ENEX should have a sound academic background in natural, engineering or material sciences or similar disciplines. Ideally he/she should have at least a 3-years work experience. Alternatively, senior managers with an economic background and additional long-standing experience in a technology-oriented business environment would suit the ENEX profile as well.
- Market experience from several industrial sectors, such as nanotechnology, polymers etc., as well as an interdisciplinary education would be an advantage.
- Furthermore, the ENEX should have good communication skills, be creative, curious about new technologies, and open for innovation in general.
- The ENEX should have pronounced soft skills in order to manage projects properly. Successful innovation management is based on a well established and efficient project management. A CEO of a German nanotechnology start-up mentioned that chief scientists in the R&D departments of companies often have social deficits, a lacking team spirit and are introverted. However, good communication skills, critical and lateral thinking as well as capabilities for problem solving and conflict resolution are crucial for pushing innovation projects.
- The ENEX should have methodical competences that enable him/her to to consolidate and improve the efficiency of innovation processes in companies. A company representative explained that young professionals with an academic degree very often have an excellent theoretical education, but missing methodical and practical skills that are necessary to apply the learned theoretical knowledge on the job. The company, for example, uses assessment matrices as a technique for problem solving in issues relating to innovation and quality management. Knowledge of and practical experience with tools like SWOT, TRIZ, Six Sigma etc. would be helpful.
- Because of its interdisciplinary approach, the ENEX profile fits very well in technical sales, project management and development operations of NT-oriented SMEs or start-ups, in innovation departments of larger corporations as well as in technology transfer offices of universities and R&D organizations.

- The ENEX should have competences in information gathering with regard to patents or technology trends as well as market and competitive analysis. He/she should be able to understand patent documentation and to draft patent strategies that might be required to achieve and maintain competitive advantage.
- The ENEX should be able to assess and prepare business, marketing and financial plans that can be used as an internal planning tool at company level or to attract capital investors.
- One crucial aspect regarding the commercialization of NT was stressed by quite a number of interviewees: not the technology as such, but benefits and added value of the NT product or service have to be clearly communicated with the customer or potential investor. Successful commercialization and thus innovation strongly depend on the technical performance of the new product or service and a competitive price. This is particularly true for technologies or products that provide incremental improvement to an existing (conventional) product, because potential customers tend to be reluctant to change a running system or a product that works. A representative of a company, a market leader and producer of CNF (carbon nano fibers) compounds, even added that his company had changed their marketing strategy and did not use the word 'nano' anymore to sell their (nano) products.
- A particular challenge the ENEX has to cope with is the interface between science and industry, for example in the framework of R&D cooperations or technology transfer and commercialization processes. Very typical for those processes and interactions is the different mindset of the parties involved, they often do not speak a 'common language'. Researchers tend to focus on the scientific aspects of nanotechnology, while there is a latent lack of market understanding and assessment of concrete business benefits associated with the specific research outputs. Companies, on the other hand, concentrate on a clear commercial focus and are interested in well analyzed business opportunities that nanotechnology can offer. Furthermore, companies (also in particular financial investors) often underestimate the ‚time-to-market', i.e. the time horizon of turning research results into viable market-ready products. They are usually looking for a fast return-on-invest. Because of his/her interdisciplinary, methodic as well as social capabilities, the ENEX should be able to help mediate those processes and overcome typical barriers of nanotechnological commercialization, equally where he is located, on the science side or the market side of the NT research-to-market process.
- The NT context of the ENEX curriculum was broadly accepted by the interviewees. Knowledge, skills and competences of the ENEX relating to nanotechnology should include i) a broad knowledge of the materials and processes used in NT applications and their systematic understanding, ii) the knowledge of advantages/disadvantages as well as limitations of different manufacturing or synthesis processes, materials and characterization techniques.
- The interviewees further agreed with the proposed selection of fields of NT application. Attention should be further given to nanocoatings and nanocomposites, which represent at present the most important fields of NT activity.
- Moreover, the ENEX should know about the potential health, safety and environmental risks relating to the production and use of nanomaterials.
- Last but not least, the ENEX should be able to create (either in a team or on his/her own) new product ideas that make use of nanomaterials and nanotechnologies, to identify

new market opportunities for and assess the market attractiveness of innovative product solutions based on the use of nanoparticles and nanoprocesses.

2.2.3 Pilot trainings

Two face-to-face pilot trainings were organized to test the contents of the ENEX curriculum and to check whether the selection of subjects chosen for the curriculum fitted the expectations of the target groups. The first pilot training was organized at MESA+, University of Twente in Enschede/NL from 25-27 January 2016 and had the focus on the nanotechnology content of the curriculum, the second training took place at the Faculty of Management of the University of Lodz, Poland from 11-12 March 2016 and concentrated on the innovation management part of the curriculum.

18 trainees (15 NL, 3 DE) from the main ENEX target groups participated in the NT pilot (3 days, in English language), 23 trainees in the IM pilot (2 days, in Polish). The feedbacks of both trainings were evaluated on the basis of pre-/post-pilot questionnaires developed by the partnership. The post-pilot questionnaires were used to evaluate the level of satisfaction of the trainees.

The NT pilot consisted of the following modules:

- Basics of nanotechnology: Top-down processing, Bottom-up fabrication, Nanocharacterization;
- Unconventional electronics;
- Storage of renewable energy;
- Early diagnostics of diseases;
- Technology venturing;
- Societal aspects of nanotechnology;
- NT applications: valorisation, company presentations, case study.

The pilot was completed by lab tours (MESA+ NanoLab, BioNanoLab, Scanning Electron Microscopy characterization lab).

The IM pilot covered lectures and workshops on the following topics:

- Introduction to nanotechnology in business;
- Assessment of the market value of knowledge/technology;
- Preparation of technology offers;
- Choosing the best strategy for commercialization of knowledge/technology;
- Technology commercialization: cases in higher education.

In both cases the trainees were highly satisfied with the selection of learning modules and the specific contents per unit. The majority of participants expressed their interest in attending the final ENEX e-learning course as soon the course is publicly available. They also declared that they would recommend the ENEX training further to colleagues, business partners and friends.

Their recommendations for additional or advanced NT/IM content were as follows:

NT content:

- Medicine and biotechnology;
- Electronics and optics;
- Materials.

IM content:

- Financial and economic value of the technology/ valuation of technology (IP);
- Specific aspects of innovation management related to the type of technology being commercialized;
- Intellectual property (IP) regulations;
- Typical examples of NT companies;
- Industry perspective case studies.

All these recommendations were considered by the partnership for refining the ENEX curriculum.

2.2.4 Desk research on education & training offers

All partners carried out desk research in their regions/ countries in order to identify education and VET qualification offers that could have an impact on the ENEX approach. The qualification offers had been separately collected and then centrally analyzed.

A major outcome of the research was that, in all participating regions, no qualification offer could be found, which follows a similar approach as the ENEX training or shows a significant overlap with the contents of the ENEX course. This finding again confirms that the ENEX course is truly unique and fills an existing market niche.

As an example, the education scene in Germany: Courses on nanotechnology or nanosciences (or subfields of nanosciences) are only offered at universities or universities of applied science. 18 master courses had been identified at universities (e.g. in Aachen, Duisburg-Essen, Hamburg, Hannover and Munich), 4 master courses at universities of applied science. Bachelor courses are offered at 15 universities and 4 universities of applied science. Only one university offers a distance learning course in nanotechnology (Technical University of Kaiserslautern: certifcate in nanobiotechnology, 2 semesters).

32 further training institutions offer training relating to selected fields of technology, amongst others, to nanotechnology, mainly in the format of specialized workshops or seminars on a commercial basis. The Berlin-based *'Steinbeis-Transfer-Institut Technologie und Innovation'* offers on request commercial customized further trainings on specific technological subject areas in combination with elements of project and innovation management. However, those trainings are not offered on a regular basis, and there was no information available as to when, or if at all, trainings on NT subjects had been carried out.

With regard to qualification in innovation management, 23 master study courses had been identified at German universities or business schools (Master of Science, MBA or Master of Arts courses). These courses do not relate to nanotechnological subjects at all.

Also in the other ENEX partner countries NT education & training is a matter of academic activity only. One singular training event with contents close to those of the ENEX NT curriculum had been identified in the Netherlands. The 3-day course *'Inzicht in Nanotechnologie'* was organized by *Euroforum*, a Duesseldorf-based company of Informa plc, in cooperation with *NanoNextNL*, the Dutch national research and technology programme for micro and nano technology, and took place in Utrecht in March 2015. The programme of this workshop had to a certain extent thematic overlaps with the NT pilot training organized in the ENEX project. As in case of the ENEX training, the course primarily addressed managers from industry and science institutions, but also policy makers, researchers, graduate students and high school teachers, in order to provide a general introduction into fundamentals, challenges and risks of nanotechnology.

In 2015, the EU funded project *NanoEIS* (http://www.nanoeis.eu) published an open courseware model curriculum as a guide for university educators to refine and improve existing curricula in the field of nanotechnology, or to set up new curricula based on the outcomes of the research carried out in the project. The objectives of NanoEIS (2012-2015) have been i) to investigate the European labour market for personnel trained in nanotechnology, and ii) to explore the relevance of existing nanotechnology education and training in universities, vocational training institutes and secondary schools for the needs of industrial and other employers. Although the NanoEIS model curriculum refers to university courses of either 1st degree (6 semesters), 2nd degree (4 semesters) as well as 3rd degree (max. 4 years), the recommendations with regard to NT content have been studied by the ENEX partners.

2.2.5 Competence units of the ENEX training course

As a result of the study described above, the following key subject areas/competence units of the ENEX training course were defined:

1. Nanotechnology (NT):
    - Introduction to nanotechnological innovation;
    - Nanomaterials;
    - Processes & Fabrication;
    - Characterization;

    Major NT application areas:
    - Nanobiotechnology & Medical applications;
    - Nanoelectronics & Nano-optics;
    - Energy.
2. Innovation management (IM):
    - Introduction to innovation management;
    - Technology commercialization;
    - Economic value assessment in the nanotechnology context;
    - Innovation marketing;
    - Intellectual property;
    - Project management in the nanotechnology context;
    - Financing of innovation management in nanotechnology;
    - Corporate and academic entrepreneurship.

Since the course addresses a wide range of professionals and graduates from different academic and vocational backgrounds, all learning modules are kept at a rather general and comprehensive level, providing all theoretical knowledge required and imparting the necessary skills and competences to apply this knowledge.

3. The ENEX Training Course

3.1 Structure of the course

The ENEX training is designed as an e-learning course and follows a modular concept. It offers a high degree of flexibility to the trainees, allowing them to decide to a large extent on an individual learning path and pace. This flexibility makes the course very appropriate for a VET qualification.

Furthermore, due to its modular and easy-to-add-on architecture, the ENEX course offers an ideal opportunity for customized further developments in the future.

The training course comprises in total 16 learning units, of which 8 units cover NT-related subjects and the other 8 units subjects related to innovation management. The general structure of the course is shown in Fig. 3.

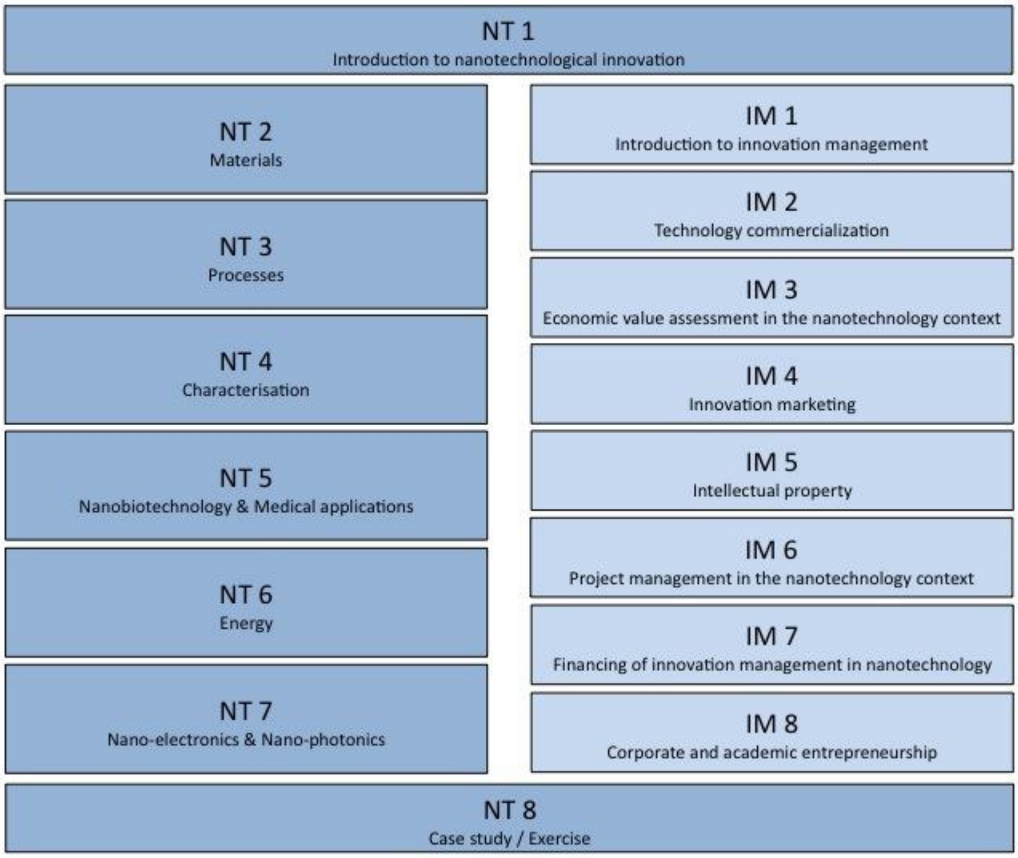

Fig. 3 *Structure of the ENEX course*

In addition to the competence units listed in chapter 2.2.5, the learning course will be completed by a case study, which each trainee has to work on during the course.

The NT modules 2-4 are regarded as the fundamental NT modules and deal with the key topics of ‘Materials’, ‘Processes’ and ‘Characterization’ (see Fig. 4). Trainees are recommended to start with theses learning units before addressing the application modules (NT 5-8). The application modules focus on ‘Nanobiotechnology & Medical applications’, ‘Nanoelectronics & Nanophotonics’ and ‘Energy’. Also the case study/ exercise (NT 8) is subsequent to the basic NT modules. The case study further contains innovation management content and therefore should be carried out in the final stage of the course.

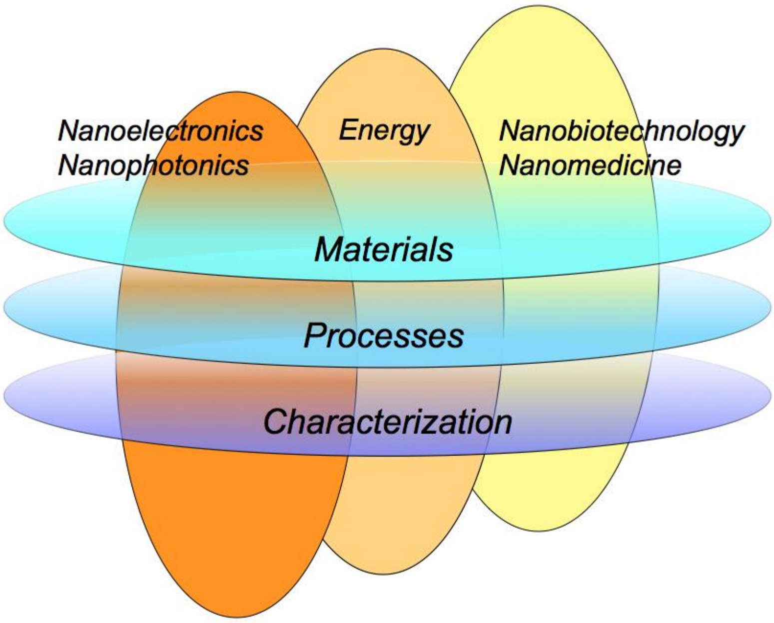

Fig. 4 *Basic elements of the nanotechnology curriculum*

The IM part of the curriculum offers maximum flexibility to the trainees. There is no preference concerning the sequence of learning units, except the first module, which gives a short introduction into the issue of innovation management and furthermore provides guidance and orientation for the other IM modules to follow, and therefore should be taken first.

3.2 Requirements for trainees

The ENEX qualification is primarily aimed at individuals who have already obtained a university degree (or similar) in natural sciences (physics, chemistry, material sciences, etc.), engineering sciences (electrical engineering, microsystems technology, mechatronics, etc.) or medicine, or have an adequate track record of industrial work experience. It is however the intention of the ENEX partnership to keep the requirements concerning the prior knowledge of the trainees as flexible as possible and fairly open to allow also business managers with an economic background, but without a degree in natural/ engineering/ material sciences to take part in the course.

The following knowledge, skills and competences are required/recommended to successfully master the ENEX qualification:

Knowledge:

- Higher education degree in natural sciences (physics, chemistry, biology, etc.), materials science, engineering sciences (electrical engineering, mechatronics, microsystems technology, production technology, etc.),
- or business experience out of the fields mentioned before (for example, a senior manager or CEO with an economic background, but working for a longer time in a technology-oriented business environment).

Skills:

- English language skills (based on self-assessment, comparable with TOEFL, Cambridge CAE, etc.);
- Good communication skills;
- ICT skills, i.e. the trainee must be familiar with common PC software (in particular, MS Office) and capable of working with Internet-based programme facilities.

Competences:

- Analytic competences;
- Competences in self-organization.

Since the training is designed as an e-learning course, the trainees must be furthermore equipped with a PC (or laptop) and must have access to the Internet.

Depending on the level of entry qualification, the trainees might have already substantial experiences with regard to individual learning modules, resulting either from formal education or professional work experience. In those cases, the trainees can skip the modules in which they have already acquired relevant competences, provided that they pass the final assessment of the modules in question. Against this background, the ENEX course can be used by professionals to check their level of prior knowledge and experience and immediately receive a certificate of the course, should they have build relevant competences in all ENEX subject areas.

3.3 Learning methodology

The method of e-learning allows trainees from all over Europe to participate in the same qualification. The ENEX course will be provided by means of the Moodle learning management system (LMS). Moodle is the most widely used and tested open source learning management system mainly used by universities and other educational institutions to store and share training material. In order to work on the course units, trainees have to log in into the Moodle platform using their personal identity and password. The Moodle LMS also provides the possibility to work directly on assignments and tests as well as take up contact to other trainees (or trainers, if involved) who are logged in simultaneously. Course units, exercises, a detailed glossary etc. are all stored on the Moodle platform and can easily be accessed by the trainees.

The training course comprises in total 16 learning units, of which 8 correspond to NT-related subjects and another 8 to innovation management. In accordance with the EQF and ECVET, each learning module is described in terms of learning outcomes (see chapter 3.6).

Each learning unit is specified in terms of its objectives, estimated duration, contents and assessment methodology and includes a range of learning materials that are needed by the trainees to acquire the theoretical knowledge and build up the skills and competences required for applying this knowledge.

The learning material used in the course includes

- Powerpoint presentations,
- Videos,
- Links to external sources,
- Case studies.

The training course will have a fixed duration of 6 weeks. The trainees will study the learning material on their own time and pace, with the obligation to do their assignments in time.

The course will start with a general introduction to nanotechnological innovation (NT 1), followed by the other learning modules with nanotechnology or innovation management content. The trainees will have large flexibility in selecting their individual sequence of learning units according to their own preferences and priority settings. It is, however, recommended to start in the nanotechnology context with modules NT 2-4 as well as in the innovation management context with module IM 1.

3.4 Assessment of trainees / Certification

The ENEX course will be offered as an open source e-learning course as required by the rules of Erasmus+ funding. The assessment of the trainees will be mainly based on self-assessment and quizzes. Each learning unit will have a final quiz consisting of multiple choice questions. The length of the quizzes will be between 9 and 12 questions. In order to get a certificate the trainee will have to pass the quizzes of all learning modules with an average score of 75% or higher. At the end of the training course, the trainees that have passed the assessment will get a Certificate of Attendance of the ENEX training programme. This (standard) certification is free of costs.

It is however intended and at present investigated by the ENEX partnership to offer an advanced option of the ENEX training, which is based on a rigorous final assessment of trainees by independent experts and certified by an accredited certifying organization. This option requires more organizational effort than the standard procedure, but adds more value to the trainee, who will receive a Certificate of Accomplishment on successful completion. Advanced level certification will be available for an extra fee that has to be paid by the trainee on enrolment.

3.5 Course classification according to EQF and ECVET

The ENEX training course corresponds to level 6 of the European Qualification Framework (EQF). The learning outcomes of level 6 are listed Tab. 1.

	Knowledge	**Skills**	**Competences**
Level 6	advanced knowledge of a field of work or study, involving a critical understanding of theories and principles.	advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study.	manage complex technical or professional activities or projects, taking responsibility for decision making in unpredictable work or study contexts. take responsibility for managing professional development of individuals and groups.

Tab. 1: Knowledge, skills and competences corresponding to EQF level 6 *(Source: EQF Recommendation, 2008)*

In accordance with the principles of EQF and ECVET, the ENEX course has been structured in units of learning outcomes that allow for better comparison and recognition of periods of successful learning.

3.6 Learning outcomes

On the following pages, the contents of the ENEX training course are listed in terms of competence units/ learning outcomes. According to the EQF and ECVET, learning outcomes are defined on the basis of knowledge, skills and competences (KSC), which a trainee should have on completion of the training:

- ‘Knowledge’ means the outcome of the assimilation of information through learning. In the EQF, knowledge is described as theoretical and represents the body of facts, principles, theories and practices that are related to a field of work or study;
- ‘Skills’ means the ability to apply knowledge and use know-how to complete tasks and solve problems. In the EQF, skills are described as either cognitive (logical, intuitive and creative thinking) or practical (involving manual dexterity, applying and using learned methods, materials, tools and instruments);
- ‘Competences’ means the proven ability to use knowledge, personal, social and/or methodological abilities in work or study situations and in professional and personal development. In the EQF, competence is described in terms of responsibility, autonomy, individual performance and social behaviour.

Following the principles of ECVET, each competence unit is described in terms of KSC.

General outcomes:

From an overall viewpoint, due to the interdisciplinary approach of the curriculum, the whole set of learning units of the ENEX course will add more value to the trainees than simply adding the KSC of each individual module. The trainees will learn to view and check nanotechnology innovation processes from several different angles: technological, economic, methodical, as well as managerial. Hence, the entire ENEX course will improve the overall capacity of the trainees and provide additional universal skills and generalistic competences that are sought by companies as well as science organizations. Trainees will typically advance in critical thinking, communication and creativity.

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
Nanotechnology					
NT 1	Introduction to nanotechnological innovation	1. What is a nanometer? 2. Definition of nanotechnology. 3. History of nanotechnology. 4. Nanotechnology is multidisciplinary and an enabling technology. 5. Major application areas of nanotechnology. 6. Nanotechnology and the living world (biology). 7. Today's nanotechnology products 8. Societal aspects to nanotechnology development. 9. Risks involved.	1. Know and understand the physical phenomena at the nanoscale as well as the limitations of classical science and technology at those dimensions. 2. Explain the differences between dominant physical processes and effects at the nanoscale and those at the macroscale. 3. Explain why nanotechnology is an enabling technology. 4. Know about major milestones in the historical development of nanotechnology. 5. Discuss various applications that can be expected from nanotechnology. 6. Know and understand a number of societal issues that arise with nanotechnology, including the risks.	1. Have a basic general understanding of challenges of nanotechnology in a wider technological and economic context. 2. Build capacity for generating new ideas relating to nanotechnology applications. 3. Be able to reflect in a holistic way on the pros and cons of nanotechnology. 4. Be sensitized to potential risks relating to the use of nano-technology. 5. Show interest and initiative in nanotechnology-related matters.	7,5

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
NT 2	Nanomaterials	1. Atoms and molecules as building blocks of nanotechnology. 2. Carbon-based structures: nanotubes (CNT), fullerenes, graphene. 3. Biomolecules 4. Nanoparticles: metals, semiconductors, colloids. 5. Polymers 6. Nanocomposites 7. Nanocoatings 8. Interfaces 9. Properties, applications, and fabrication methods of nanomaterials.	1. Classify nanomaterials in terms of properties, applications and fabrication methods. 2. Know and understand the interdependence of processes/ applications and (groups of) nanomaterials. 3. Know and understand the different fabrication processes for nano materials.	1. Develop a systematic understanding of the use of nanomaterials (in combination with nanotechnology processes), enabling to draft (simple) product solutions based on nano-technology and prepare (or take) decisions at management level. 2. Be capable of selecting suitable nanomaterials for perspective industrial applications. 3. Build capacity to adapt to new situations relating to the use of nanomaterials. 4. Have knowledge of typical limitations concerning the use of nanomaterials in industrial fabrication processes.	10

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
NT 3	Processes & Fabrication	1. Top-down processing of nanostructures and nanomaterials. 2. Bottom-up fabrication. 3. Nanoparticle synthesis. 4. Photolithography. 5. Etching techniques. 6. Ultra-thin film deposition techniques. 7. Imprint techniques. 8. Fabrication of nanocoatings.	1. Know and understand the difference between bottom-up and top-down techniques. 2. Set up a basic process outline for the fabrication of a given nanostructure. 3. Know about distinguished applications of nanoparticles and nanostructures as well as successful innovations.	1. Develop a systematic understanding of the use of nanotechnology processes (in combination with nanomaterials) for typical applications, enabling to draft (simple) product solutions based on nano-technology and prepare (or take) decisions at management level. 2. Be able to decide on the best fabrication process for a given application. 3. Be capable of selecting suitable combinations of processes and materials for typical industrial and medical applications. 4. Have a systematic understanding of the limitations and advantages/ disadvantages of specific nanotechnology processes for the fabrication of nanostructures, nanocoatings or nanoparticles. 5. Be capable of generating new ideas relating to the use and integration of nanostructures, nanocoatings and nanomaterials in industrial applications.	10

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
NT 4	Characterization	1. Optical tools. 2. Scanning probe techniques. 3. Electron microscopes. 4. Spectroscopy techniques. 5. X-ray techniques.	1. Know about the fundamentals of techniques used in nanoanalytics. 2. Identify a characterization technique for a proposed problem. 3. Explain the differences between individual electron microscopy techniques. 4. Explain the differences between individual scanning probe techniques. 5. Know and understand the limitations of the techniques used in nanoanalytics.	1. Develop a systematic understanding of the use of characterization techniques used in nanoanalytics. 2. Be capable of selecting suitable characterization techniques for typical industrial and medical applications. 3. Be able to explain the advantages/ disadvantages and limitations of individual characterization techniques for specific fields of application. 4. Be able to decide on the best characterization techniques for a given application.	10

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
NT 5	Nanobiotechnology & Medical applications	1. Early diagnostics of diseases (nanosensing). 2. Nanomedicine and controlled drug delivery. 3. Lab-on-a-chip devices 4. Organ-on-a-chip systems. 5. Bio-inspired nanostructured surfaces (superhydrophobic, antibacterial).	1. Translate technology to a medical application. 2. Identify the restrictions of such devices. 3. Identify the sectors where bio-inspired nanostructured surfaces are needed. 4. Explain the basics of organ-on-a-chip devices and the fabrication of these systems. 5. Design a basic device for a given problem.	1. Develop a systematic understanding of the basics of nanomedicine (targeted therapeutics). 2. Build interdisciplinary competences (technology, economics, environment, society) by learning about successful product innovations based on nanotechnology. 3. Build capabilities in problem-solving and designing basic medical devices for (simple) applications.	10

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
NT 6	Energy	1. Energy harvesting. 2. Conversion of energy. 3. Storing energy. 4. Utilization.	1. Know and understand the basics of the discussed techniques and applications. 2. Set up a basic device structure. 3. Identify possible application environments for a given basic technique, for example two fluidic channels for blue energy harvesting.	1. Develop a systematic view of the opportunities that are opened up by nanotechnology in the energy sector. 2. Build interdisciplinary competences (technology, economics, environment, society) by learning about successful product innovations based on nanotechnology. 3. Build capabilities in problem-solving and designing basic device structures for (simple) applications relating to the harvesting, conversion, storage and utilization of (renewable) energy.	10

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
NT 7	Nanoelectronics/Nano-optics	Nanoelectronics: 1. Introduction into nano-electronics. 2. CMOS scaling, Moores law and beyond Moore. 3. Spintronics. 4. Quantum dots and quantum wires. 5. Magnetic random access memory. 6. Magnetic nano-oscillators. 7. Organic electronics, Molecular devices, single molecule transistors. Nanophotonics: 8. Plasmonics. 9. Photonic crystals. 10. Nano-optics in nanomicroscopy techniques.	1. Describe in basic concepts the quantum mechanical effects important for nano-electronical and nano-optical devices. 2. Discuss about the viability of the Beyond Moore devices like single molecule transistors. 3. Explain in own words the basics of spintronics. 4. Know the difference between the individual types of plasmons. 5. Has a rough understanding of photonic crystals, their underlying theory and their application as well.	1. Develop a deeper understanding of the differences between state-of-the art electronics and the design of next generation electronic systems based on nano-electronics. 2. Have a sound understanding of the limitations of conventional electronics when scaling down to the nanoscale. 3. Build interdisciplinary competences (technology, economics, environment, society) by learning about new electronical system designs based on nanotechnology. 4. Build awareness about future technological developments and develop forward-looking abilities.	10

	Competence unit/ Learning outcome	**Knowledge** The trainee should know about ...	**Skills** The trainee should (be able to) ...	**Competences** The trainee should ...	**Hours**
NT 8	Case study/ Exercise	This is the closing module of the course, in which elements of the nanotechnology modules and the innovation management modules will be merged into one interdisciplinary exercise. The trainee will be given a relevant problem, for which a solution based on nanotechnology needs to be found. After having solved the technological problem, a continuation into innovation management issues will follow. Central questions in this part of the case study are "how do you protect your solution", "how will you divide your money stream", and "how will you market your solution".	1. Look at a problem with a multi-disciplinary mindset. 2. Think outside the box when a problem is given. 3. Start already thinking about innovation management issues in the first stages of the problem-solving process. 4. Combine nanotechnology know-how with innovation management processes into a report.	1. View problems from different angles and develop multidisciplinary understanding. 2. Build capabilities in critical and analytical thinking. 3. Develop competences in problem-solving and decision-making. 4. Enhance communication and presentation skills.	10

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
Innovation management					
IM 1	Introduction to innovation management	1. Basic concepts of innovation management. 2. Types of innovation in organizations. 3. Characteristics of innovation processes.	1. Know the basic concepts of innovation management including creativity/ idea generation, technology commercialisation, technology transfer etc. 2. Know about the various types of innovation as a source of competitive advantage of companies. 3. Know about various approaches to innovation processes, including technology push/ market pull, interactive and non-linear processes, value chain and the nanotechnology research-to-market (R2M) process.	1. Develop a critical understanding of the complexity and heterogeneity of research-to-market processes and innovation management. 2. Build capabilities in interdisciplinary and analytical thinking.	4

	Competence unit/ Learning outcome	Knowledge The trainee should know about ...	Skills The trainee should (be able to) ...	Competences The trainee should ...	Hours
IM 2	**Technology commercialization**	1. Building competitive advantage of a modern enterprise. 2. Commercialization of R&D output. Stages of the nanotechnology research-to-market (R2M) process. 3. Innovation and commercialization strategies. 4. Strategic partnerships. 5. Management competencies in the area of technology commercialisation.	1. Understand the principles of commercialization processes. 2. Identify critical milestones/ bottlenecks in the nanotechnology R2M process. 3. Know commercialization strategies and how to adapt them to nanotechnology R2M processes. 4. Identify market characteristics and market opportunities.	1. Develop a systematic and general understanding of the complexity of nanotechnology R2M processes. 2. Be able to understand the process of commercializing R&D output from different angles (researcher, company manager, investor etc.). 3. Develop analytical competences and creativity. 4. Build social competences and communication skills.	12

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
IM 3	**Economic value assessment in the nanotechnology context**	1. Economic value assessment. 2. Technology readiness levels (TRL). 3. Criteria for determining the economic value of a technology. 4. Valuation of R&D output. 5. Key competences and key tasks of a commercialization/ technology transfer manager. 6. Presenting the outcomes of economic value assessment.	1. Understand the process of economic value assessment. 2. Assess the level of technology readiness for a given research outcome. 3. Write technology offers/ requests based on R&D outcomes/ company needs. 4. Know the methods for assessing the economic value of industrial property rights (IPR) and how to apply them. 5. Write business reports relating to economic value assessment.	1. Be capable of understanding the interrelation between product maturity and economic value. 2. Enhance capacities in analytical thinking. 3. Build capabilities in decision-making. 4. Enhance communication and presentation skills.	10

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
IM 4	**Innovation marketing**	1. Market analysis. Sources of market information. 2. Product structure and its quality characteristics from the supplier's and user's point of view. 3. The product in the value chain. 4. Marking products. 5. Product lifecycle management. 6. Developing product innovations. 7. Promotional tools for innovative products/ services.	1. Know where and how to find market information and carry out market research. 2. Analyze market segments and the competitive milieu. 3. Understand the stages of the product development process. 4. Knows the basic principles for the assessment of new product ideas. 5. Identify opportunities for developing ideas for product innovation.	1. Develop market intelligence capabilities. 2. Build capacities in information gathering. 3. Enhance analytical competences. 4. Enhance creativity. 5. Develop communication skills. 6. Build methodic competences (marketing).	12

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
IM 5	**Intellectual property**	1. Intellectual property rights (IPR) legislation. 2. Types of IPR. Procedures for establishing IPR. 3. Patents. Paths for patent protection. Rights and obligations related to patents. Infringement, misappropriation, and enforcement. 4. Trade secrets. 5. Patent databases. 6. Types of IPR agreements. 7. Licensing.	1. Know categories of IPR and the differences between them. 2. Know procedures for the protection of intellectual property. 3. Understand the structure of patent documents and the importance of patent claims. 4. Develop an IP strategy for a given case. 5. Know the most important sources of patent information and how to retrieve information from patent databases. 6. Know the basic structure and aims of IPR agreements and how to use them. 7. Understand the structure and most important phrases of license agreements.	1. Understand patents as assets, think proactive and be sensitized to protecting IPR in the early stage of nanotechnology R&D. 2. Be able to analyze patents and draft IP strategies and/or commercialization strategies baased on IP. 3. Be capable of using patent databases as important tool for technological information and novelty search. 4. Develop communication and negotiation skills (licensing).	8

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
IM 6	**Project management in the nanotechnology context.**	1. Business planning. 2. Creativity techniques in innovation management. 3. Developing IPR strategies. 4. Implementation of research results. Stakeholders/ benefits matrix. 5. Business model canvas. 6. The commercialization plan. 7. Management techniques for nano-technology/ product development projects.	1. Know appropriate management tools supporting the understanding of complex nanotechnology research-to-market processes and how to apply those tools. 2. Understand the purpose, contents and how to develop a business/ commercialization plan. 3. Elaborate and present a commercialization plan. 4. Know the principles and basic tools of project management relating to technology/ product development .	1. Build analytic competences. 2. Develop social competences: communication skills, empathy, team-working abilities. 3. Build leadership capabilities. 4. Build methodic competences (coaching, use of innovation and project management tools).	20

	Competence unit/ Learning outcome	Knowledge The trainee should know about ...	Skills The trainee should (be able to) ...	Competences The trainee should ...	Hours
IM 7	**Financing of innovation management in nanotechnology**	1. Management and financing of the innovation process. 2. Economics of innovation. 3. Stages of development and innovation funding. 4. Financing innovation in the nanotechnology research-to-market process. 5. Sources of research funding. 6. Equity financing. 7. Gaining investors: types of investors, search for investors. 8. Preparing and presenting offers for investors and other target groups/ stakeholders. 9. Cooperation with investors.	1. Know and understand the process of commercialization of research results. 2. Elaborate a financial plan as part of the commercialization plan (or business plan). 3. Know and understand the decision-making process of commercialization strategies based on analysis of the available financing sources and other relevant factors. 4. Know the rules of preparing presentations for an investor and how to apply them. 5. Know the basic conditions for the preparation of an investment agreement for the implementation of research results.	1. Develop analytical competences. 2. Enhance creativity. 3. Enhance communication and presentation skills.	8

	Competence unit/ Learning outcome	Knowledge The trainee should know about …	Skills The trainee should (be able to) …	Competences The trainee should …	Hours
IM 8	**Corporate and academic entrepreneurship**	1. Intrapreneurship: invention generation and technology development. 2. Academic entrepreneurship: new technology commercialization in the university context. 3. Corporate entrepreneurship: entrepreneurial technology commercialization within large companies. 4. Innovation processes and IPR in the context of public and private organisations. 5. Spin-off as a form of technology commercialization. 6. Organisational aspects of large entities (universities, corporations): culture, decision-making process, interpersonal relations, hierarchy issues etc.	1. Know the conditions of the organizational process of commercialization of R&D within public research institutions and corporations. 2. Know the legal requirements relating to the process of commercialization of R&D within public research institutions and corporations. 3. Know the legal forms of commercialization of scientific research and its main features. 4. Know the managerial tools for interacting with employees of public research institutions.	1. Develop entrepreneurial thinking. 2. Enhance creativity. 3. Be a team player and/or be able to coordinate a group of people. 4. Develop capabilities relating to conflict-solving and decision-making. 5. Develop communication skills. 6. Build networking capabilities.	8