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DOCTORAL PROGRAMS AND TRAINING: EUROPEAN PERSPECTIVES

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Abstract

The paper gives an overview of the European new approach to the doctoral programs, by considering the actions for the innovation of the doctoral training, mainly based on Salzburg principles and Salzburg II Recommendations and the strategies to support European doctoral programs.
The European Commission measures to enhance the quality of the doctoral training and to support the doctoral programmes are valued.
Finally models for doctoral training among some European State members are described.

1. Introduction

This paper aims to give an overview of the doctoral programs and training in Europe and to analyze future perspectives.
It is mainly based on official documents edited by the European Commission, Directorate General for Research & Innovation (Bologna Process).
The European country members agreed about ten years ago on the importance to have a consolidated liaison between higher education and research. Universities are entrusted with this task, by the integration of the European Higher Educational Area (EHEA) and the European research area.
To fulfil this scope the Ministries decided to concentrate efforts on the reform of the Doctoral Research program according to common development lines. These lines are reported in *The European Higher Education Area - Achieving the Goals Communiqué of the Conference of European Ministers Responsible for Higher Education, Bergen, 19-20 May 2005.*
In the document the European Ministers stated that the Doctor's degrees must adopt an approach based on learning outcomes, in agreement with the Higher Educational Policy and Governance.
Moreover they pointed out the requirement to enforce the structure of the doctorates and make transparent the tutorial and evaluation procedures. The duration of the program is ranging from 3 to 4 years, in the different countries and the young person following a doctoral program should have a double function: student and researcher at the same time (this is generally true, but in the conference this concept was enforced). Eventually the Ministers pointed out also the importance of the interdisciplinary aspects of the doctoral education.
The great attention given to the learning results, to the Doctoral courses program, to the interdisciplinary and transversal aspects and to the "critical mass" for the organization of a fruitful research activity have as a final goal the improvement of the know-how and of the innovation and to train the Research Doctors for the job market.

2. European new approach

To fulfil the requirement to enforce the structure of the doctorate for the integration of the European Higher Educational Area and the European Research Area, European Universities member of European University Association (EUA) outlined some principles to address a reform of the doctoral studies: they are known as Salzburg Principles. In Salzburg (2005) was held one of the Bologna Seminar, and ten principles have been enunciated. They are the basis for the development of doctoral programs

and are reference points for the doctoral upgrade process (Bologna process), successively supported by further recommendations.
In 2008 the Council for Doctoral Education (CDE) was stated for coordination and monitoring of activities.
In Lovanio 2009 and Bucharest 2012 Ministers agreed upon the necessity to satisfy the job world requirements on advanced professional education, ranging interdisciplinary and transversal knowledge, no longer limited to a specific discipline. The Ministers took the action to support and improve the integration among education and research at all higher educational levels. Moreover they underlined the need to establish the higher education on the more advanced and recent research, in order to enhance innovation and creativity in the young people. Eventually they take the commitment to improve the number of persons able to perform research activities. Obviously this fact is conditional to the economical capabilities of the different countries.
The academic career is even less attractive for young people with respect to alternative solutions always in the research field. Although the responsibility for making attractive the careers in the field of the research areas is still in the hands of Public Authorities and of higher level education institutions (London 2009).
In Spring 2014, Professor Geoffrey Boulton, from University of Edinborough opened the Cesaer Association conference, with the question: *We attract, recruit, train for what?* As a matter of fact data relative to 96000 PhDs from 4000 institutions were presented, considering their job capabilities: 53% of them finds a job outside the research field area, 17% in the outside university research area, 25% place themselves equally in the two previous categories, after a period of early stage researcher. Only 3.5% remains as permanent staff in the University and only 0.45% of them becomes professor.
On the other hands industries and universities even more collaborate to European higher educational levels. An example is the establishment of ”industrial” doctoral programs, as collaboration of universities and industries.
Moreover the Ministers pointed out the important role of the international mobility both for students and professors, to enhance exchanges of knowledge in the different research fields and to increase the offer of jobs and careers. The recruitment procedure for professor should be open in order to attract in universities and research centers distinguished professors and researchers.
Recently (Bucharest 2012), as a conclusion of the analysis of the guidelines defined in 2005 and successively by EUA, the Ministers took the action to further increase the quality, the transparency and the mobility within the doctoral program. As a matter of fact, the efforts already done are not sufficient to guarantee the effective contribution of universities to the innovation and the liaison between high education European area and research European area.

3. Principles for Innovative Doctoral Training

Principles for Doctoral training to ensure innovation have been stated in the "Report of Mapping Exercise on Doctoral Training in Europe - towards a common approach", 27 June 2011(final), issued by European Commission, Directorate General for Research & Innovation, Directorate B - European Research Area, Unit B.2 "Skills”. They are seven and mainly addresses to: 1) excellence of the research, 2) interdisciplinary research options, 3) international networking, 4) transferable skills training, 5) exposure to industry and other relevant employment sectors, 6) quality assurance, 7) attractive institutional environment.
They are resulting from the analysis performed by experts from university associations, industry and funding organizations and have been endorsed in the Council conclusions on the modernization of higher education, Brussels, 28-29 November 2011.
The Report of Mapping Exercise on Doctoral Training in Europe provides a detailed overview of the most recent developments in doctoral training and outlines a common approach. It is

essential to define this approach, in order to fully support the principles identified in the document itself. To obtain the expected results new supporting measures are required. The Report includes ideas for those measures and suggests strategies both for European Union and for the single Member States.

The doctorate plays an important role in enforcing the competitiveness of European industry, if the economic system is able to absorb a great number of new researchers. Therefore having a common training program, defined in cooperation between academia and industry, it will increase the strength of European economy. This is particularly true in the aerospace area, where innovation is essential and interdisciplinary aspects are more evident.

It is important to focus resources on doctoral training, because this is the way to enable researchers to be employed in a wide range of areas.

As a matter of fact, across European union a large number of doctoral candidates are involved in EU founded projects and work together in different disciplines.

In the Green Paper *"From Challenges to Opportunities: Towards a Common Strategic Framework for EU research and innovation funding"* (Feb. 2011), the need of an optimized integration of various funding schemes to enhance the EU research activities was well traced, in view of the new Framework Programme Horizon 2020. The document proposes a common understanding based on the international experience and possible implementation mechanism for doctoral training.

The attention on doctoral training raised considerably in more recent years, due to the understanding of the close relationship between new knowledge and society progress. In technical areas this is evident since long time, due to the very rapid innovation: the aerospace area is one of the evident example, as well as climate changes and healthy.

Among initiatives to identify and promote a new view of the doctoral training, the most significant is the EUA already mentioned (Salzburg principles and Salzburg II Recommendations).

Even if the research profession needs to become more attractive in Europe, the number of researchers in the EU has been increased since 2000 at a faster rate than in US and Japan in those years. However in 2008 the percentage researchers versus employees was 6/1000, in US 9/1000 and in Japan 11/1000. The difference is mainly due to the lower number of researchers in the business area (46% of total numbers of researchers in EU, against 68% in Japan and 79% in US). In China the number of researchers doubled from 2000 to 2007 (from 0.7 million to 1.4 million). In 2011 there were about 600000 doctoral candidates doing research in EU and 110000 graduating every year.

In 2011 the ERA Steering Group on Human Resources and Mobility discussed a roadmap on doctoral training, taking into account the significant changes occurred in doctoral training during the last decade. Nevertheless it is still important to convince the managers of SMEs of the value of employing doctorate holders and of the consistent contribution they can give to the company development, due to innovation research experience matured during the doctoral activity.

4. Strategies to support European Doctoral Programs

EC founding streams are important available means for doctoral programs, together with the national and international support programs (in Italy, for instance, part of the founds come from the Education, University and Research Ministry and from the University budgets).

The doctoral training issue became even more important in the more recent years, because of its role in the development of new knowledge for the innovation process. Looking in particular to the aerospace area, it is crucial to develop new mechanisms to support the training and to prepare the candidates to the industrial and economic context.

To achieve this goal, the cooperation between the academia and the industrial tissue is of paramount importance.

European Commission is working on the integration of the various founding scheme, to support the EU research effort, represented in

particular by the Horizon 2020 Framework Programme.
Recently specific strategies to train a consistent number of researchers have been decided by Member States, to meet their R&D targets and to offer attractive job conditions in public research institutions. These strategies obviously include gender considerations. Among the Members the evolution of the strategic initiative is different and the results are more evident in some States and less evident, presently, in others.
European Research Area Steering Group on Human Resources and Mobility (ERA-SGHRM) in 2011 discussed a roadmap to define these strategies. It was evident that the doctoral training should be included.
It is true that significant changes have occurred in doctoral training during the last decade, even in relatively "young" doctoral programs (i.e. in Italy were this year only the XXX course will start).
Further improvement in the field of doctoral perspectives will not depend only on the quality of the training, but are strongly correlated to the capability of the national/international economy to absorb new researchers. It is mandatory to convince the managers of small and medium enterprises that they will add value to their companies by employing doctoral holders, as already mentioned in Section 3..
In 2012 European Commission proposed, on the basis of the provision on ERA in the Lisbon Treaty, an ERA framework and supporting measures for mobility and cross-border cooperation. They had the aim to ensure: 1) the quality of the doctoral training as well as attractive employment condition and gender balance in the research careers; 2) Mobility of researchers (across different countries and different areas), including the open recruitment in public research institutions, with common, or at least comparable, career structures.
In particular for doctoral training the European Commission proposed a common approach to make the future generation of doctorate holders active contributors to the European innovation. The recommendations for doctoral training, to fulfill this scope are based mainly on: 1) critical mass; 2) transferable training; 3) ability for candidates to challenge disciplinary borders; 4) encourage doctoral candidates to spend some research time abroad and in industry or in other private or public research areas.
At European level, ERA-SGHRM coordinates the work on doctoral training and stakeholders from industry and academia are obviously involved in this process. This activity includes Marie Curie Actions, Erasmus Mundus, Structural Founds and national initiatives. It has been finalized in early 2011. A cross-check of the results was carried on in 2012, through a feasibility study, involving visits to successful doctoral schools.

5. Quality of Doctoral training

It is evident by the previous remarks that the doctoral training must be based on the progresses in knowledge, through the originality of the research. Although the research must meet the needs of the industrial market, whose requirements are more extensive than the academia's ones.
Nevertheless it is recognized that universities still remain the accredited institutions for awarding doctorates.
A number of initiative take care of the doctoral training, as already mentioned (EUA, Salzburg I and II- Principles and Recommendations , Council of Doctoral Education). The Salzburg Principles (see Section 2.) are considered the most detailed and comprehensive document available as guideline for doctoral training.
Other initiatives are listed below.
The League of European Research universities (LERU) prepared a paper describing its "beyond 2020" vision on doctoral training: high level of the research, capability of doctoral candidates of driving complex changes in the society, training in international, interdisciplinary, intersectoral context.
The Coimbra Group described the most important requirements for doctoral training. It defined standards for the independence and quality of the research, the supervision, the duration of studies.
Looking outside Europe, there are a number of initiatives, like the US Council of Graduate Schools, the Canadian Association of Graduate

Studies, The Deans and Directors of Graduate Studies (Australia), the Association of Chinese Graduate School. These groups, together with EUA, agreed upon Banff Principles on Graduate Education.
In the United States the US Council of graduate Schools (CGS) and the Educational testing Service (ETS) formed a joined commission that produced the extensive report "The Path Forward, The Future of Graduate Education in the United States". It includes the outlines for a successful doctoral training in US. The report includes data on demographics and growing competition from Europe and Asia. It underlines the need to provide transferable skills training for US doctoral candidates. The advances made by EU countries are clearly taken into consideration. It has to be noticed that the industrial position (in particular small and medium enterprises) toward the doctoral holders is more positive than in a number of other countries.

6. Organization of the doctoral training and supporting measures

The organization of the doctoral training in Europe is varied and depends on the university profiles, on the national rules, on the resources available and, obviously, on the disciplines.
The traditional model, as the master degree follow-on, is changing and the programmes pay more attention to the career development.
The doctoral training can be organized at different levels (local, regional, national, international), depending on the institution tradition. Very often the universities offer a mixed models: local generic courses and specific courses together for candidates from different institutions. The majority of European Institutions opted for a structure for doctoral schools or programs across several disciplines. This fact permitted to give to the candidates the transversal skills already mentioned for their future career.
Some countries (Norway, the Netherlands, Ireland) offer national thematic doctoral facilities (or research schools). Other countries stated agreements for international training network (Personal Training, Marie Curie Actions, Erasmus Mundus).
Many universities began collaborative research with other institutions, like joint programmes, leading also to joint or double degree. In some cases the collaboration is with research institutes or with industries and with other bodies supporting innovation. In these cases the supervision of the research activity of the candidate must be shared among the bodies.
Some universities are able to offer master and doctoral programmes. So they are able to identify and eventually recruit good candidates for the research activity from the master programmes
Approximately half of European doctoral candidates are women. In specific aerospace filed the percentage is still lower.
The recruitment is on international base. Therefore a more competition for positions available increases the quality.
Many institutions have a monitoring system, to trace the career of the candidates after graduation.
The schemes to support doctoral training in Europe are both at national level and at European level, where the most well-known, specifically dedicated to the optimization of the doctoral training, are the Initial Training Networks (ITN) of the Marie Curie Actions, - now Marie Sklodoswska-Curie Actions - (estimated more than 18000 doctoral candidates have been supported during FP7 by Marie Curie Actions). ITN consist of three steps: European Training Networks, European Joint Doctorates, European Industrial Doctorate.
Among other funding sources, Erasmus Mundus supported 1400 doctoral candidates in seven years. Other programmes, not specifically focused on doctoral training founded the doctoral training as well, like Erasmus (estimated 35000 candidates), European Research Council (13000 candidates), Cooperation Programme of FP7 (estimated 70000, considering one per project participation), Structural Funds (estimated more than 50-100000) and Development Aid Programmes (estimated 1400).
Due to the limited budget of EU programmes, they cannot support all training needs in all

European Research Area (in view of the envisaged one million new researchers' jobs).
Therefore a special attention to the doctoral training has been paid in the design of the new generation of EU programmes started in 2014, based on the "triple I" policy: International, Interdisciplinary, Intersectorial mobility.
As future aim, attention should be given to enhance the capacity of grow for doctoral training in less developed regions, also with the use of Structural Founds. There regions should be able to be confident in the founding procedure, not only for specific research, but also for the doctoral training related research.

7. Models for doctoral training among European State members *(Member States contributions and terminology)*

In this Section are considered examples of models for doctoral training in some European countries, paying attention to peculiar aspects already mentioned, like university-wide doctoral training, thematically organized doctoral training, international cooperation, doctoral training in cooperation with industry and other relevant employment sectors, skills training.

Belgium

Since 2000 Flemish universities organized thematic and interdisciplinary doctoral schools according to EUA principles. These Schools offer training (including transferable skills) to doctoral candidates. They link their doctoral programmes to labour market outcomes.
The organization of these schools is fully autonomous. Starting from 2011 they receive a specific funding of 4 Million EURO from the Flemish government to finance the doctoral education.
Flemish doctoral schools have a common platform in the framework of the Flemish Interuniversity Council. Their doctoral courses are open to students from other universities.
All Flemish universities provide a well-balanced offer of courses, both domain oriented and transferable skills. Ghent University, for example, offers seminars in transferable skills within four separate clusters: Communication Skills; Research and Valorization; Career Management; Efficiency and Leadership.
The Baekeland programme funds doctoral projects that are executed at a Flemish university in close cooperation with a company. The PhD candidate is supervised jointly by an academic and an industrial supervisor and spends a considerable amount of time at the company.
Projects are co-funded by the company and the orientation of the research project should be strategic.
In Federation Wallonia-Brussels, the doctorate (postgraduate studies, minimum duration three years) is organized within universities and consists of two parts:

- ✓ the doctoral training (60 ECTS/European Credit Transfer and Accumulation System credits). It leads to grant a research training certificate,
- ✓ the work dealing with the preparation of the doctoral thesis (corresponding to at least 120 ECTS). It leads to the conferral of the academic title of doctor, after defending the thesis.

Application for a doctorate: the student must submit a draft thesis, sufficiently defined, and obtain a written agreement of a supervisor from a university.
The doctoral candidate becomes member of a research team (within a university) affiliated to a thematic Graduate school.
The thematic and interuniversity Graduate Schools are associated in Graduate Colleges attached to the Fund for Scientific Research (F.R.S.-FNRS). 21 Graduate Colleges (écoles doctorales près le F.R.S.-F.N.R.S.) are in charge of hosting, coordinating and promoting the creation of thematic, interuniversity, interdisciplinary and international Graduate Schools. Currently there are 50 recognized Graduate Schools.
The Federation Wallonia-Brussels is supporting transversal trainings that can be developed with the private sector within Graduate Colleges.
The universities of the Federation Wallonia-Brussels are fully autonomous in the field of learning transferable and entrepreneurial skills.
In the last few years, priority has been given to transferable skills and languages (credits

dedicated to transferable skills, specific seminars, human strategies for researchers, etc.). Wallonia also supports the doctoral trainings in cooperation with industry through the FIRST SPIN-OFF scheme in order to improve the scientific and technological potential of the research units and to train the future managers in the fields of emerging technologies. The scheme has been set up with a view to inciting the university researchers to develop new industrial products.

Denmark

Aarhus University organized doctoral training at four large PhD schools, focused on courses in transferable skills, because of the recognition that even more PhD candidates will continue their career in the public or private sectors, instead in the academic area (see Section 2.).

The doctoral training is close linked to postdoctoral training.

In 2010 Universities Denmark established a national framework agreement for two types of PhD courses:

- ✓ A model for subject-specific PhD courses where students can participate freely in subject-specific courses at other PhD schools. The providing PhD school's own PhD students have priority of 80 % of the seats whereas external PhD students have 20 %.
- ✓ A model for mutual binding co-operation which consists of an open market for subject specific courses. This co-operation is organized in professional networks between the PhD schools' research education programmes to ensure a high academic level and critical mass of participants. So a long-term agreement on an adequate number of relevant courses with a relative even allocation of resources is made.

All doctoral candidates at the Faculty of Engineering, University of Southern Denmark, are enrolled in the PhD school which is subdivided into six research training programmes:

- Applied Mathematical Modelling
- Energy and Environmentally Efficient Technologies
- Functional Materials and Nanotechnology
- Information and Communication Technologies
- Product Design and Innovation
- Robotics

Each programme is interdisciplinarily anchored in a Research Training Programme Committee (RTP Committee). The RTP Committee's role is to advise the PhD School in academic matters, as well as to academically assist the research training programmes in terms of construction, operation and development of the academic studies within each field.

In the field of the international cooperation, Denmark established a Sino-Danish Chinese Industrial PhD programme. The purpose of the industrial PhD Programme for China is to further the development of the Danish knowledge intensive business community by strengthening the relationship between Danish and Chinese science and technology communities.

The Industrial PhD project stretches over three years conducted in cooperation between a private company, a university and the Industrial PhD candidate. The student is employed by the company and enrolled at the university and divides his or her time between the two workplaces. The programme includes subsidies to cover the students salary, travel expenses and tuition.

The Danish Agency for Science, Technology and Innovation has so far granted around DDK 13 Million to the programme specifically aimed at Chinese PhD students.

Moreover an Industrial PhD project is a three-year business project where the student is hired by a company and enrolled in a university at the same time. The company receives a monthly wage subsidy, while the university has its expenses for supervising etc. covered.

The PhD student works full time on the project and divides his or her time equally between the company and the university. In 2010, DKK 134 million has been allocated (as opposed to DKK 104 million in 2009) for new Industrial PhD projects. Accordingly, it is assumed all qualified applications from the private sector will receive funding. Last year, more than half of all applications were approved.

France

In September 2010, 285 doctoral schools (Ecoles Doctorales) were accredited by the Ministry of Higher Education and Research within the framework of an agreement on objectives between the State and universities (contrats d'établissements). The doctoral candidates were 70000.

Established by-law on August 7th, 2006, doctoral schools help to structure the offer of doctoral training contributing to its visibility and to its attractiveness at national, European and international levels.

The doctoral schools provide training and development of doctoral trainees, scientific supervision and preparation to occupational integration.

They are organized into wide disciplinary fields, themselves subdivided into research expert groups. For example: Mathematics and their interactions (75 doctoral schools), Physics (164 doctoral schools), Earth science and the universe, space, chemistry (149 doctoral schools), Engineer sciences (343 doctoral schools), Sciences and technologies of information and communication (324 doctoral schools).

A Doctoral school may cover several fields: it may be mono-disciplinary or multidisciplinary.

The Programming law for Research of April 18th, 2006 allows French higher education and research institutions to establish joint entities designed to give more visibility to French research especially in terms of international rankings.

These joint entities called "PRES" and formed as "public institutions for scientific cooperation" (établissements publics de cooperation scientifique) ensure the pooling of activities including the coordination of doctoral schools.

The French higher education institutions take part in joint-supervised international doctoral training (co-tutelle internationale de thèse).

International partnerships can also be structured in European or International colleges.

At the University of Strasbourg, the European Doctoral College gives to thirty doctoral trainees the opportunity to prepare joint-supervised doctoral research projects, involving the University of Strasbourg and a university or research organization of a country chosen by the doctoral trainee.

Moreover the Programming law for Research of August 7th, 2006 on doctoral training includes several actions aiming at bringing together doctoral training and socio-economic sectors. The reform of the training frame includes two major trends regarding doctoral training cooperation with industry and other relevant employment sectors: refocusing doctoral programs on the preparation to occupational integration and better link doctoral training and R&D in socio and economic sectors.

Germany

German Universities have recently established so called *Graduate Academies* or *Research Schools*. They are university-wide structures for the training of doctoral candidates, acting as one-stop information and support centres for doctoral candidates. They offer and coordinate various programmes, provide networking possibilities and ensure good standards in training and supervision.

One example is the Graduate Academy at the University of Jena. It trains doctoral candidates, as early stage researchers, for their professional career in science, business and society. The programmes combine disciplinary and interdisciplinary topic, specially tailored courses in transferable skills and an intensive individual supervision by a team of internationally recognized faculty members. Other German universities (e.g. Bremen, Bochum, Freiburg, Halle, Hannover, Heidelberg, München, Stuttgart, Rostock) have similar structures, for several sectors.

Graduate Schools (as part of the German Excellence Initiative) serve as an instrument of quality assurance in promoting young researchers and are based on the principle of training outstanding early stage researchers within an excellent research environment. Graduate schools thus offer ideal conditions for doctoral candidates within a broad scientific area and, as integrative institutions with international visibility, they encourage the doctoral candidates to be active members of their academic and social communities. Graduate schools extend beyond DFG (German

Research Foundation) Research Training Groups and differ from them substantially. They should also contribute to the strategic development of the university.
International Max-Planck Research Schools are an example for doctorate in cooperation between universities and other research institutions. Within the International Max Planck Research Schools (IMPRS) German and foreign junior scientists are offered the opportunity to earn a doctorate in the excellent research and learning environment of selected Max Planck institutes in close collaboration with neighbouring universities and other – sometimes foreign - institutions. Other research organizations like the Helmholtz-Gemeinschaft (HGF) or the Leibniz Association offer similar graduate programmes.
Research Training Groups (Graduiertenkollegs) are established by universities to promote young researchers. They are funded by the DFG for a period of up to nine years. Their key emphasis is on the qualification of doctoral researchers within the framework of a focused research programme and a structured training strategy. Research Training Groups with an interdisciplinary approach are welcome. The aim is to prepare doctoral researchers for the complexities of the job market in science and academics and simultaneously to encourage early scientific independence.
They provide opportunities for joint doctoral training programmes between German universities and universities abroad. The research and study programmes are jointly developed and supervised. Doctoral students in the programme complete a six-month research stay at the respective partner institution.
Some R&D intensive companies have developed close collaborations with universities for the sake of training of the future generation of leading researchers. They fund the positions for the doctoral researchers and provide space in their labs for them to carry out their research. The doctoral researchers belong to a university, are formally employed by it.
They carry out a project defined by the company, but following strict academic standards.
KIT/Daimler is one example of such a joint graduate school of the Institute for Technology in Karlsruhe (KIT) and the Daimler AG (as part of the Project House e-drive), financed by Daimler and funded by the Ministry for Science, Research and Art Baden-Württemberg. During the four year doctorate, the candidates spend most of their time doing research at the KIT, but also work in Daimler AG research and development departments. The programme comprises an obligatory three months stay at a company or research institution abroad and is open to other interested industrial partners.
Doctorate in cooperation with Audi is another example where more than 80 doctoral candidates take part in the research projects (in technical studies as well as humanities) funded by Audi in close cooperation with 10 universities. The overall aim of the projects is to expedite the transfer of knowledge between research and industry as well as the promotion of young researchers.

Ireland

University College Cork (UCC) offers a wide range of modules to develop generic and transferable skills of doctoral candidates, from induction to research to career planning and commercialization of research. A particular focus has been placed on development of communication skills: competitions and events are planned, where students are challenged to present their work to a non-specialist audience.
These initiatives have then been integrated into a range of structured PhD models within UCC's Graduate School system, which range from highly structured models in key thematic areas to more flexible arrangements, where the courses taken are tailored to the individual researcher and project area.
The Dublin Region Higher Education Alliance (DRHEA) Graduate Education Strand aims to propose in the Dublin region an International Centre for Graduate and in particular, Doctoral Education, by combining the strengths of the participating institutions.
The DRHEA Graduate Education Strand has established an inter-institutional network in the disciplines of Biomedical Science, Chemistry, Economics, Engineering, Physics and

Politics/Sociology and Public Policy. Disciplinary Leaders provide advanced discipline specific modules and master classes available to all doctoral students in the alliance.
Moreover in 1998 the Program for Research in Third-Level Institutions (PRTLI) has awarded 1.22 billion EURO (including exchequer and private matching funds) to date into strengthening national research capabilities via investment in human and physical infrastructure. A core part of this programme is collaboration across seven universities to develop national graduate schools with structured PhD programmes in thematic areas across all disciplines. The 4-year PhD programmes facilitate inter-institutional training in generic and discipline-specific skills and, in some cases, provide laboratory rotations, internships and industry placements. Some examples of the thematic programmes funded by this scheme include Digital Arts & Humanities, Engineering, Natural Sciences, Molecular Medicine, Inflammation, Electricity Research and Physics.
An example of thematic training is the Programme for Research in Third Level Institutions (i.e. INSPIRE – Integrated Nanoscience Platform for Ireland. It is a consortium of eight Irish third level institutions with international leading research capability in nanoscience and nanotechnology. It has funding of over 31 million EURO. It is a collaborative framework for nanoscience research and graduate education. It provides shared access to advanced instrumentation, graduate courses and new strategic research partnerships.
The Enterprise Partnership Scheme is an innovative initiative through which Irish Council for Science Engineering and Technology (IRCSET) links with private enterprise and eligible public bodies to award co-funded postgraduate scholarships and postdoctoral fellowships to the most promising researchers in Ireland. Benefits include: mentoring from industry experts, placement opportunities, exposure to commercially orientated research environment, transferable skills, relationship with a potential future employer. The industry partner provides 30% of the funding. There are over 160 companies involved in the funding of 350 doctoral candidates.
The Irish Universities Association's (IUA) Deans of Graduate Education Network developed a skills statement of PhD graduates' skills, attributes and qualities, based on an analysis of skills statements already developed and in use in North America, Europe, Australia, New Zealand and elsewhere. This skills statement contains common characteristics of the generic outcomes that result from the research education experience and identifies competencies that are transferable to the workplace, either academic or non-academic.
The TCD-UCD Innovation Alliance, launched in 2010 by the Irish Prime Minister, is a radical new partnership between Trinity College Dublin(TCD) and University College Dublin (UCD). The TCD-UCD Innovation Academy is the educational focal point of this Alliance and is a collaborative educational venture between TCD and UCD, involving interactions with external agencies from both the for-profit and non-profit organizations. The Academy is transforming the doctoral education experience by establishing innovation alongside research and education as an integral element of the doctoral programme. The output will be a new breed of graduate, expert in their discipline, but with the creativity and entrepreneurial skills to convert knowledge, ideas and inventions into products, services and policies for economic and social benefit.
Students are anchored in the disciplines, where they will pursue original research relevant to key strategic objectives. The Innovation Academy offers a collaborative Graduate Certificate in Innovation & Entrepreneurship to PhD students from across both institutions.

Netherlands

Since 2005 the Dutch PhD system provides a fixed salary scale, contract periods education and supervision plan. To decrease costs, some universities currently appoint PhD candidates on the basis of a grant. In doing so, these universities attempt to provide a place for more PhD candidates for the same amount of money, thus improving productivity at the cost of the

employment benefits of future PhD candidates. Accordingly, doctoral candidates are not entitled to social benefits, such as the right to maternity leave, pension benefits and sickness pay. As a consequence a PhD project could become less attractive compared to other positions.

The new 'graduate schools' (with very different forms emerging now) provide localised PhD courses, and take away some of the responsibilities of the National Research Schools. However, the recent experience is that both levels (national Research Schools and local Graduate Schools) play a role, in a kind of matrix organization.

The Netherland doctoral system is based on the *National Research schools*. Since the early 1990s national research schools became the main organizations for research. In 1992 the Royal Netherlands Academy of Arts and Sciences was asked to create a specific body (Evaluation Committee for Research Schools/ECOS) to accredit and – in rounds of five years – re-accredit these research schools. Universities attached great value to these evaluations. Most of the research time of senior scholars, and all regular PhD projects, had to be incorporated into these research schools.

Currently, there are about 100 re-accredited research schools in the Netherlands, some of them also with research partners in Belgium (Flanders).

Switzerland

The Doctoral School of the École Polytechnique Fédérale de Lausanne represents a significant example of the Switzerland Doctoral Schools. At EPFL the doctoral candidates are distributed across eighteen doctoral programs. Each doctoral program is responsible for recruiting doctoral students, organizing their supervision and regular evaluation, and monitoring their progress. The doctoral programs also organize an offer of advanced level courses and create a community based in their scientific domain. The doctoral programs are designed to reach transversally across the EPFL's faculties in order to bring together researchers from different domains.

In 2010, the EPFL Doctoral School had over 1900 enrolled doctoral students, 3270 applications, and nearly 400 annual graduating PhDs.

The majority of EPFL's doctoral students have a dual status as employee, with a contract as doctoral assistant in their research lab on a set salary scale. This employment contract includes a 20% teaching requirement.

The EPFL doctorate has a normative duration of four years, with a definitive admission process (including a candidacy exam) at the end of the first year.

For 2012-2016, the Rectors' Conference of the Swiss Universities (CRUS) has launched, complementary to existing institutional doctoral schemes, a national programme aiming at offering young scientists inter-institutional programmes that enable research networking and better integration. CRUS' long-term objective is to offer appropriate training schemes for the majority of doctoral students. The doctoral programmes that will be funded have to correspond to the Joint Position by the Swiss universities on the Doctorate and to fulfil a set of criteria regarding supervision, inter-institutional cooperation as well as to the programme's research topic. The responsibility for the implementation modalities of their doctoral programmes lies with the individual universities.

Building on earlier cooperation in 2005 the CUSO (Conférence universitaire de Suisse occidentale - Doctoral Programmes Western Switzerland University Conference) began to set up joint doctoral programmes (as supportive and complementary structures) designed to provide doctoral students with in-depth scientific and methodological courses and seminars, and to help them in acquisition and perfecting their transversal and transferable skills. The programmes also offer many occasions for networking and socialization: as early-stage researchers, doctoral students need to become well-acquainted with the scientific community in their field, including its rules and values. CUSO funds are available for purposes of coordination, inviting speakers from abroad, organizing residential and in-house seminars, and reimbursing students' travel costs from their

universities to the sites of seminars. From January 1, 2011 there were 22 programmes in operation, with 1500 students enrolled.
StartingDoc Programme started in 2008 and is a "group-mentoring" programme addressed to women at the very beginning of their academic career. It concerns beginner doctoral from the universities of western Switzerland and the Federal Institute of Technology Lausanne (EPFL) and is financed by the Federal Equal Opportunity at the Universities Programme. StartingDoc offers PhD students useful tools to succeed through their academic path. The programme is open for all disciplines and therefore it focuses on the structural aspects, which are required to achieve a PhD thesis, such as milestones of the academic path, researcher rights, work management, network building and publications.
Life Science Zurich Graduate School is an example in areas of joint complementary competence. ETH Zurich operates joint doctoral programmes with the University of Zurich: Life Science Zurich Graduate School, with partial involvement of the University of Basel (Plant Science).
A "Cotutelle de thèse" is a bi-national doctorate with a supervisor both in the candidate's home university and in a partner university abroad, leading to a joint diploma (either a diploma issued jointly by the two institutions or two separate diploma, specifying the nature of the doctorate as a "cotutelle de thèse"). Swiss national authorities provide funding for "Cotutelles" between Swiss universities and universities of neighbouring countries (Austria, France, Germany, Italy) in order to cover the travel and residence expenses of both the doctoral candidate and his/her supervisor. Not all universities make use of this possibility.
Many of the research groups at Swiss universities, notably at the two Federal Institutes of Technology, maintain close collaboration with industrial partners. Various models of industrial doctorates are possible, what is important for the success of an industrial PhD is a common understanding of all partners implied and an active involvement of all partners all along the dissertation work.

In the Swiss understanding, the purpose of the doctorate is not only the development of academic competence and the acquisition of subject specific and methodological knowledge and skills, but also the acquisition of transversal knowledge and skills as well as the promotion of academic interaction and networks according to European indications. In this way, the doctorate prepares candidates for research-based professions at universities or other institutions (public sector, business, administration) and enables them to take on diverse high level responsibilities and functions.
ETH Zurich requires all doctoral students to take a certain amount of coursework ("doctoral studies"). These courses are considered both as a right and an obligation of the students to continue their professional development. The objectives of doctoral studies are to enable doctoral candidates to acquire knowledge and skills in the field of their doctoral thesis, in cognate disciplines and in interdisciplinary areas; to integrate themselves into the scientific community. At least one-third of the required credits must be outside the candidate's research field, covering e.g. transferable skills, entrepreneurship, career development, communication or pedagogic skills.
Since 2000 the Federal Equal Opportunity at the Universities Programme has been financing Mentoring Programmes for the promotion of female junior researchers at all Swiss universities in collaboration with the two Federal Institutes of Technology and the Swiss National Science Foundation (SNSF). It intends to promote female junior researchers by giving them career related advice independent from their direct supervisor and introducing them into the academic networks. In doing so the concept of mentoring is broad and includes also gender specific skills training e.g. in rhetoric, job applications, appearance etc.
Due to the different cultures of the faculties, there is also faculty-specific mentoring.

8. Italian model for doctoral training

In Italy networks among Universities are organized to improve the quality of doctoral training in specific programmes and to increase the critical mass of doctoral candidates.

Mobility of the candidates among the participant Universities is established on the basis of specific agreements.
While no national rules for the organization of doctoral schools have been defined, some Italian Universities set up schools to coordinate structured doctoral programmes following the "Salzburg principles". These follow two models: thematic schools and University Doctoral Schools (where programmes in different fields are coordinated in a single university structure).
Since 2013 the Ministry of Education, University and Research issued a decree, where new rules for the accreditation of the doctoral centers and programmes are established and the criteria for the programmes are listed.
The universities, the research institutions, the university consortia (at least one Italian) can establish doctoral programme after the accreditation by the Ministry. To be accredited, the institutions must demonstrate the international research level of the doctoral scientific board, to have the capability to find autonomous funds, as integration of the ministerial ones, to offer proper structure to accommodate the doctoral candidates, to offer programmes in specific disciplines, transversal disciplines, in research management and collaborations with European and international research organization. First time an industrial doctorate has been stated, where industry employees can become doctoral candidates after a selection.
The doctorate programme has a normative duration of three years.
Aiming at internationalization of doctoral training, many Italian doctoral schools have calls for admission open to foreign candidates.
The Italian Ministry of Education, University and Research has a yearly call for doctoral fellowships in topics related to industrial research open to all Italian universities hosting doctoral courses / programmes on these topics. The requirements for fellowship assignment include agreements with foreign Universities for research collaboration, double degree, PhD joint-supervised programmes, and geographical and inter-sectorial mobility plans for the admitted candidates. Some universities additionally attract funding from private companies and non-academic institutions to increase the number of fellowships on the most innovative industrial-research programmes.
For its accreditation the doctoral programme must also give information on the future expectation for candidates in the research sector outside University and in the industrial research field.
Funds are recruited by government (Italian Ministry of Education, University and Research), universities budget, industry, research institutions.

9. Politecnico di Torino Experience in Engineering Doctoral Programme

Politecnico di Torino is a research university, offering BA degree, MS degree, doctoral degree. The students are 32000 (2014), 30% of them are women and 700 doctoral candidates.
The doctoral school offers, in 2014, 13 internal doctoral programs, 3 programs in agreement with University of Torino and 1 with INRIM Research Centre. Moreover are present international specific agreements, European initiatives (Erasmus Mundus, Marie Curie, etc.) disciplinary high level courses, interdisciplinary courses and courses given by international scientists.
Recruitment (national and international candidates) is done through the evaluation (by a professors evaluation board) of a document, prepared by the candidate, explaining his/her scientific interest and motivations to apply for the doctorate, an abstract of the Master thesis and the *curriculum studiorum*. The evaluation board proceeds to a final interview with candidates before the preparation of the admission list. The doctoral students receive a grant from the Ministry of Education, University and Research; or from external sponsors.
Starting in Fall 2014 the Politecnico di Torino has decided to invest incisively on the doctoral research programs by ratifying a set of PhD program support policies: an increase for all fellowships of the active cycles, a budget for sporadic national and international mobility (i.e. travel costs from University to the sites of seminars and conferences) and, on a yearly

basis, the allocation of 100000 EURO for prizes to be awarded to the best doctoral candidates of each program, according to a scheme defined together with the programs' Coordinators.
In conclusion Politecnico di Torino is addressing a great attention to the doctoral training. The meaningful investment approved represents a steady increase of 2,5 million EURO in the resources allocates for the active PhD programmes, with the intent to strengthen the role of the doctoral research activity.
Moreover industries and research institutions make available budgets for grants on specific research themes.
The majority of the doctorate holders finds a job in the industry and in the research institutions, immediately after the defense of the thesis.

10. Conclusions

A great renewal process started in the last decade among European Union countries to define innovative doctoral training procedure. This activity focused to the new research requirements in terms of innovation and transversal skills, both for specific academic and research institutions and for industries. One of the main scope was to give good perspective to the new doctorate holders.
The new European Framework Program H2020 makes large room for doctoral training, with the aim to support the figure of early-stage researcher and to strengthen the connection between doctorate and industries/research centres.

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References

1. http://ec.europa.eu/euraxess/pdf/research_policies/Report_of_Mapping_Exercise_on_Doctoral_Training_FINAL.pdf
2. http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/educ/126375.pdf
3. http://ec.europa.eu/euraxess/pdf/brochure_rights/am509774CEE_EN_E4.pdf
4. http://www.eua.be/eua-work-and-policy-area/research-and-innovation/doctoral-education/doc-careers
5. "Research Careers in Europe Landscape and Horizons", European Science Foundation 2010
6. Report of Mapping Exercise on Doctoral Training in Europe"Towards a common approach",27 June 2011, EUROPEAN COMMISSION DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION Directorate B - European Research Area Unit B.2 "Skills"
7. http://www.esf.org/fileadmin/links/CEO/ResearchCareers_60p%20A4_13Jan.pdf
8. http://ec.europa.eu/education/higher-education/doc1261_en.htm
9. http://www.eua.be/eua-work-and-policy-area/research-and-innovation/doctoral-education/doc-careers
10. *http://www.eua.be/cde/about-euacde/euas-work-on-doctoral-education.aspx Europe 2020 Flagship Initiative Innovation Union COM(2010) 546 final of 6.10.2010*
11. *http://ec.europa.eu/research/innovation-union/pdf/innovation-unioncommunication_en.pdf#view=fit&pagemode=none*
12. http://www.cgsnet.org/portals/0/pdf/mtg_banffprinciples.pdf

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