Skills and Competences of a Doctor of Engineering

Michael H.W. HOFFMANN
Institute of Microwave Engineering, University of Ulm
Ulm, Germany

and

Manfred NAGL
Department of Computer Science 3, RWTH Aachen
Aachen, Germany

ABSTRACT

Not only in Europe but also on other continents, it is felt that a reform of the doctoral phase in tertiary education is necessary. To make this reform a success, it is necessary to first define the skills and competences of a doctor in general and of a doctor of engineering in particular to dispose of measurable criteria for the outcomes of the reform. These criteria are intended to foster not only an academic career but also careers in industry and administration, i.e. to support the careers of future chief executives. It is also presented how these skills and competences are seen by industrial companies as well as by the young Doctors of Engineering. Finally, it is discussed how existing methods might be reformed to further improve the doctoral phase at and in cooperation with universities.

Keywords: Doctorate, tertiary education, knowledge, skills, competences.

1. INTRODUCTION

In the framework of the Bologna-process [1], a reform of higher education including its highest level, the doctoral phase, has been initiated in Europe. Obviously, it is felt – not only in Europe, as recent papers [2], [3] demonstrate – that existing models of PhD education need to be adapted to modern requirements. Different motivations drive this development, and different visions exist on how to proceed.

While it appears that motivation of politicians and representatives of administration, commerce and industry is more driven by economical and societal arguments, academia seems to concentrate more on aspects of research, or of pedagogy in the tertiary sector. As a consequence discussions often end up in disappointing results, since debaters talk at cross-purposes.

Therefore, in order to discuss on a sound, verifiable basis, it is necessary to first define the skills and competences, doctors should have acquired in contrast to those of masters or of bachelors, and to distinguish between skills and competences of a doctor in general from those of a doctor of engineering in particular. Only then, sensible requirements might be formulated to describe requirements for skills and competences of a doctor of engineering in a modern environment, and priorities might be set judiciously.

2. ACHIEVING COMPETENCES AS RESULT OF A SPECIALIZED LEARNING PROCESS

Differentiation between different subject areas

Educational politicians and institutions of the tertiary sector of education agree upon that bachelor-degree, master-degree and doctoral degree are seen as evidence of different professional skills and competences of their holders. Curiously enough, there is not a similarly strong agreement on what these skills and competences ought to be, and to what degree they should be achieved, let alone how they might be assessed.

Since about six years, however, increasing though slow convergence in these questions is observed. First promising steps were done 2002, when a group of stakeholders of the Bologna-process discussed on the differences between skills and competences of graduates of the first and second cycle of higher education. As a result, they formulated the Amsterdam Consensus of shared descriptors for bachelors and masters [4]. These descriptors were the starting point for a complete set of descriptors that also included the doctorate [5], and which were the archetype for a set of descriptors in the European Qualification Framework [6]. Eight levels of qualification are described there, the three highest ones of which are the reference levels for the bachelor degree, the master degree, and the degree of a doctor.

The problem with these descriptors is that they were designed mainly by learning-theorists who did not distinguish between learners of different specific fields. However, a short view into habits and methodologies applied in medicine, laws, philosophy, and economics, just to mention a few, shows that there might be enormous differences. Even in closely related fields of expertise, like in chemistry and physics, requirements might differ considerably. This is not only a theoretical differentiation, as dissimilarly long typical durations for the doctorate in different subjects show.

As a consequence, it is necessary to distinguish between general skills and competences on the doctoral level, and particular skills and competences of a doctor of engineering. Since it might be suspected that even between different fields of engineering there might be differences of required skills and competences, the authors of this article have discussed these problems with their colleagues from the fields of electrical and information engineering, of computer science, of mechanical and process engineering, and of civil engineering and geodesy. The authors of this article are actually representatives of different areas of engineering. The results of these discussions are incorporated in the following paragraphs.

Acquisition of knowledge, skills and competences

The degrees of a bachelor, a master, and a doctor are awarded as evidence of a successful learning process, where learning is not only learning by heart, but a process that – beside others – incorporates “a change in an individual’s behavior or ability to do something” [7].

In the parlance of educational policy, therefore, the terms “knowledge”, “skills” and “competences” are used as in learning theories known from pedagogy and from psychology. Unfortunately, there is no commonly agreed definition of these terms, which does not come as a surprise, if it is considered that about hundred more or less differing learning theories exist [8].

Nevertheless, there is quite wide agreement nowadays that the process of learning is cyclic. Typical learning theories that emphasize this point are Kolb’s experiential learning theory [9], which is particularly well accepted in US industry, or the models of Gagné and his colleagues [10], [11]. Engineers see this aspect as part of a feedback-control loop of learning [12].

Quite coarsely, a learning cycle starts with the recognition (and storage) of a new set of facts, which then will be experienced in a particular context, thus leading to conceptual knowledge. To make use of the new knowledge, action schemes are developed and trained in order to react advantageously, if a similar constellation of facts in a similar context occurs. This is achievement of procedural knowledge. Application of procedural knowledge, in simple situations and environments, leads to recognition of new facts thus closing this cycle of learning and initiating another cycle. People who act predominantly on this background of knowledge are said to be trained, or semi-skilled.

For more complex activities, being trained is not enough. For these, a broad basis of known facts and the context(s) they are related to is necessary. Based on knowledge about similar facts in different contexts, or on knowledge about different facts in a similar context, rules must then be experienced that are common to several constellations. This is acquisition of canonical knowledge, which has another quality as compared to acquisition of simple procedural knowledge. People who dispose of canonical knowledge in at least a specialized field are said to be skilled in this field.

In contrast to factual, conceptual, and procedural knowledge, canonical knowledge enables to adapt to changing situations, since by application of known rules on new facts in a known context, adapted procedures might be realized.

After acquisition of canonical knowledge, two different directions of development might be thought of. The most obvious one is to start new cycles of learning in order to broaden the basis of knowledge underlying the acquired canonical knowledge, and to apply the latter to practical problems in that field. People, who have successfully performed several of these steps are said to be *professionally experienced in a more application-oriented field.*

Another way of development would be the acquisition of canonical knowledge through analysis, which enables the learner to find or complete the set of universal rules behind facts in contexts and behind procedures. This is a typical research-oriented methodology. Someone who disposes of these competences is said to be *professionally experienced in a more research-oriented field.*

Sound canonical knowledge is the prerequisite for the most advanced form of acquiring new knowledge, which is called strategic knowledge. It is gained by evaluating what would happen, if a set of rules that works in one context would be transferred to a different context, or what would happen, if rules would be broken. By simulation of these situations, it might happen that completely novel relations would be recognized, and that new ideas would be thought. This is the way how new theories or new works of techniques or art might be created. People with these competences are said to be creative in their fields of expertise.

Definition of terms

In the light of the above given explanations, definitions of the terms “knowledge”, “skills”, and “competences” are discussed subsequently.

According to the European Qualification Framework (EQF) [6], *knowledge* “means the outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of study or work”.

With reference to the same source, it is found that *skills* mean “the ability to apply knowledge and use know-how to complete tasks and solve problems”.

Competence, finally, “means the proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and/or personal development”.

Unfortunately, parlance of the EQF does neither comply with Bloom’s taxonomy of learning [13], nor with that of most learning models. Therefore, the terms are *redefined* as follows [14]:

Knowledge related to a field of work or study, means the learnt, retrievable information on facts, the context, to which facts are associated, and the rules interrelating facts to contexts.

Skills means an ability that has been acquired by *training* and that makes use of the implicit memory, to apply knowledge to standard situations, and to use know-how to complete *standard* tasks, and to solve *standard* problems.

Competence means the proven ability to autonomously recognize interrelations between facts and the contexts to which they are linked, to apply this ability to systematically develop new methods, and, if indicated, to apply them to changed situations. This includes application to work or study situations, and in professional and personal development.

3. SKILLS AND COMPETENCES OF DOCTORS IN COMPARISON TO THOSE OF BACHELORS AND MASTERS

General skills and competences of bachelors, masters, and doctors

With the new definitions and the above described steps of acquiring knowledge, it is now possible to mark-off the skills and competences of doctors in comparison to those of masters and bachelors. This includes also social skills and competences!

- Bachelors must
    - dispose of a sound basis of factual, conceptual and procedural knowledge of a field of work or study;
    - dispose of canonical knowledge demonstrating mastery required to solve problems in a *specialized field* of work or study;
    - have the competence to manage professional activities or projects, taking responsibility for decision-making in their *specialized field* of work or study contexts;
    - take responsibility for managing professional development of individuals and groups as part of procedural knowledge on the social sector.

- Masters must
    - dispose of *in-depth* canonical knowledge of a specialized field of work or study, as the basis for original thinking. This includes disposition of critical awareness of knowledge issues in a field and at the interface between different fields;
    - be able to apply their canonical knowledge in their field of work in order to adapt their working methodologies to modified or changed situations, and to integrate knowledge from different fields;
    - be able to manage and transform work or study contexts that are complex, difficult to predict and require either new practical or scientific approaches as a step towards acquiring strategic knowledge;
    - take responsibility for contributing to professional knowledge and practice and/or for reviewing the performance of teams as part of canonical knowledge on the social sector.

- Doctors must
    - dispose of an *excellent canonical knowledge* in *several specialized fields* of work or study, as the basis for own *creative work* to enhance strategic knowledge;
    - demonstrate autonomy and sustained commitment to the further development of new ideas or processes by scientific application of canonical and strategic knowledge contexts;
    - be able to circulate knowledge and ideas they have compiled and created and to guide and instruct less qualified members of their team, which includes a good understanding of canonical knowledge on this field of social competences;
    - be able to acquire financial and other means for bringing forward their work, which is another field of social competences.

The above given descriptors are quite close but not congruent to those given by the European Qualification Framework (EQF) [6]. In contrast to these, they confine the different levels of qualification more to the different types of knowledge. They adapt the requirements to existing reality, since it must be kept in mind that the descriptors shall apply to holders of the degrees at a point in time when the degree is awarded.

This might be demonstrated using one of the EQF-descriptors as an example. There it is required that bachelors "dispose of advanced knowledge of a field of work or study, involving a critical understanding of theories and principles". This descriptor is much too ambitious, since critical understanding of theories and principles supposes thorough canonical knowledge not only of one special field, but also of comparable knowledge on other fields. Therefore, it does not coincide with the reality of average engineers.

It might well be that this descriptor applies to so-called chartered engineers (CEng [15]) or to professional engineers (PE [16]) or similarly qualified engineers. These titles are qualifications awarded to bachelors with degrees from accredited universities, having passed additional exams, and with professional experience of some years. However, as the demanding requirements for earning such a licensure demonstrates, there is several years of experience and of further learning after achievement of a bachelor degree needed to finally acquire the attested competences.

Note that the above formulated requirements for a master's degree have some similarities to those of a CEng or PE, with the distinction that the CEng or PE acquires his or her competences mainly by qualification "on the job", while a university master's is achieved mainly by university courses.

Having a closer look at EQF descriptors suggests that these are requirements for desirable intentions rather than descriptors of an actual state. The above given descriptors require, therefore, an ambitious, yet realistic set of general skills and competences for the degrees of bachelors, masters, and doctors, based on an advanced learning model.

Acquisition of competences needs time

It is a truism that learning needs time. However, with the described learning model, it might be shown in detail which parts of the learning-process need time and why. The given descriptors show a clear dependence.

Committing facts to memory needs time due to necessary repetitions and to repeated retrieval. Configuration of conceptual knowledge needs repeated retrieval of facts in a context, which is only possible after successful learning of facts. Procedural knowledge needs frequent exposure of oneself to standard situations in a context and training of procedures. Constitution of canonical knowledge requires active and own comparison of procedures in different contexts. Acquiring strategic knowledge builds on simulation of changed rules in contexts.

This makes clear that it takes the more time to constitute knowledge the more advanced the type of knowledge is that is affected.

If there is agreement that bachelors have canonical knowledge only in a limited field (at least in the first time after having been awarded the degree), and if it is agreed that the doctorate needs a much broader basis of canonical knowledge in order to develop strategic knowledge, then it is obvious that the necessary time must be spent to acquire this knowledge prior to acquisition of strategic knowledge.

Finding the rules behind facts and thus acquisition of canonical knowledge might need more or less time depending on the field of studies. In some empirical sciences, for instance, there are subfields where only few rules, but an immense body of facts in contexts, are known. In these special fields, shortening of the time duration by waiving of a subset of facts (confinement to a still more specialized field) is possible (though maybe not desirable).

In all sciences using mathematics as their describing tool, many rules have been found and it turned out that these are designed hierarchically. That means, before getting to know an advanced set of rules, other sets of rules must have been learnt first. This makes clear that mathematics-based sciences need a good part of time for learning mathematics in the beginning. Abbreviating the duration of learning by limitation to a restricted field is often not possible! Also, verification of rules in the context of models – as it is necessary in natural sciences and engineering – needs considerably long time. It is thus plausible that these methods give reasons for larger time consumption as for example in juridical sciences.

It is thus obvious that acquiring knowledge might need more or less time, depending on what special field of work or study is to be learnt. This time aspect is apparently not adequately considered in the EQF-paper [6]. Concurrent requirement of skills and competences and, at the same time, of a time frame must, therefore, result in contradictions. This is particularly felt in engineering.

4. SKILLS AND COMPETENCES OF DOCTORS OF ENGINEERING

With the above given definitions and exemplifications, it is now possible to describe required skills and competences of engineers more concretely. As a comparative study [17], [18] shows, perceptions about these requirements differ not only from country to country, but also between academia on one side and commerce and industry on the other side.

Requirements from academia

In many countries, the degree of a doctor of engineering is only a necessary interstation of academic career at a university. Its main function is to give evidence of the holder's general skills and competences as defined above. In most European countries, the degree attests additionally the holder's ability

- to *autonomously* make accessible new sources of knowledge, particularly in their respective fields of expertise in engineering sciences, based on thorough canonical and strategic knowledge in those fields of mathematics, natural sciences and computer sciences that are the scientific basis of their special studies;
- to *autonomously* develop that knowledge using a scientific methodology, thereby analyzing and evaluating complex technical problems, and proposing creative solutions;
- to *self-containedly* circulate that knowledge in a suitable form to others, mainly by their thesis, or by presentations at national and international conferences, and by peer-reviewed publications, thereby enhancing the body of technical knowledge in their fields of expertise.

While the required scientific quality of the results is normally very high, the expected degree of autonomy and originality might vary considerably from country to country. In countries, where still the educational ideals of Wilhelm von Humboldt [19] are applied with respect to the doctorate, the required degree of autonomy is particularly high. At these universities, it is also required that a doctor of engineering be able

- to autonomously supervise less qualified engineers;
- to autonomously manage a research-project as a head of a research group;
- and to *autonomously* acquire financial and ideal means for supporting his or her project. Ideal means in this sense include maintenance of international scientific contacts and cooperation.

It is thus not only an academic profile that is required from these doctors.

Requirements from commerce and industry

Due to the fact that in many countries, the degree of a doctor is normally only appropriate for an academic career but not for a career in commerce and industry, there are often only weak and unspectacular requirements to doctors of engineering.

This is completely different in Germany, which to the knowledge of the authors is the only European country where explicit requirements from industry are available concerning skills and competences for doctors of engineering[1].

The VDMA Association, a non-profit organization, representing German machinery and industrial equipment manufacturers, has carried out a representative study [20] about their requirements concerning skills and properties of doctors of engineering. The most interesting result is that 85% of the polled enterprises voted to be satisfied (66%) or even very satisfied (19%) with the skills and competences of doctors of engineering in Germany!

A more detailed analysis of the study reveals a good overview on the profile of skills and competences that is expected from doctors of engineering by German industry.

68% of the polled enterprises said that the academic, research-oriented profile be very important. Virtually the same percentage (67%) voted the actual profile would fit to that requirement. Therefore, more than two third of the enterprises appreciate this profile.

However, additionally to what is required by academia, German commerce and industry requires improved competences in

- personnel management;
- project management and management tools;
- entrepreneurship;
- networking and international contacts.

(For a more precise analysis, it is referred to the study).

[1] There is actually a study available from the Career Space Consortium in the United Kingdom on required skills and competences of bachelors and masters. However, the study excludes explicitly the doctorate. See for example: European Centre for the Development of Vocational Training - CEDEFOP, 2001.

Taking into consideration that German machinery and industrial equipment manufacturers have an internationally excellent standing, the study might be seen as evidence for an appropriate profile of skills and competences that doctors of engineering from German universities are achieving in the average. At the same time, it gives hints on how to improve.

In contradistinction, doctors of engineering from universities in some other European countries are experiencing a lacking appreciation by industry and commerce. This was reported on an international workshop about the engineering doctorate [17] by experts from Belgium, France, Italy, and Ireland. There, it was stated that for a career in industry, the degree of a doctor of engineering would not be advantageous.

Desirable skills and competences

From the above, it might be concluded, that the requirements from academia with the amendments from German universities and with strong emphasis on autonomous acting, together with the additional requirements by commerce and industry are appropriate descriptors for skills and competences of a doctor of engineering.

This is indeed seen in a similar way by doctors of engineering from German universities who are working in commerce and industry. The above cited study confirms that in more detail. It is worth recalling that more than 90% of doctors of engineering from German universities dot not stay at university after completing the doctorate, since they continue their professional career in commerce and industry. Indeed, in Germany, the engineering doctorate is seen as a part of the professional career rather than education.

As a result of the VDMA study and the information collected from colleagues in Europe, the following profile of desirable skills and competences for doctors of engineering is summarized. They have meanwhile found their way into the Bologna Handbook in a slightly different formulation [21].

Thus, a doctor of engineering should be able to:

- autonomously make accessible new sources of knowledge;
- autonomously develop that knowledge using a scientific methodology;
- self-containedly circulate that knowledge in a suitable form to others;
- autonomously supervise less qualified engineers;
- autonomously manage a research-project as a head of a research group;
- autonomously acquire financial and ideal means;
- skillfully perform personnel management;
- autonomously manage technical and scientific projects;
- act as entrepreneurs;
- cultivate networking and international contacts.

5. HOW TO IMPROVE THE DOCTORATE OF ENGINEERING

With the above analysis in mind, it appears to be evident that the doctorate of engineering could and should be improved. It would be a waste of human resources, if doctors of engineering would only find appropriate opportunities of work at universities. The example of engineering doctors in German commerce and industry shows that this might be different. However, the VDMA study shows also that the doctorate as normally done in Germany is not yet optimum.

The above list of desirable competences has one outstanding characteristic, and this is autonomy. It is indeed the ability of engineering doctors to work autonomously that German industry and commerce appreciates most. Therefore, cultivating this ability must have priority. Any educational plan that attempts to deliver these competences like in school must fail: Acquiring skills and competences, the most essential property of which is autonomy, cannot be learnt by classroom studies. It must rather be acquired by self-contained experience.

What is likely to be underdeveloped in many engineering doctorates is advancement of entrepreneurship, and this includes skilful acting in all what concerns the commercial welfare of an enterprise.

What could be improved considerably in quite a number of European doctoral programs is the advancement of social competences with respect to leadership and guidance. A potential chief-executive must be able to motivate people, to integrate individuals in a team, and to clearly address guidelines. Again, this cannot be learnt by imitating, it must be experienced in teams.

A suggestion for achieving these competences is to let future doctors of engineering lead their own groups in a research project, for which they also have financial responsibility. This must be done under the supervision of an experienced professor, whose duty is not rigorous control but consultancy. Here is another point where the doctorate might be improved, not by organizational means, but by continuing education of professors!

Doctoral candidates must have the opportunity to apply for their own scientific projects, in order to be able to get to know project management with all its facets, including financial aspects. In order to learn how to give advice to less experienced engineers, they should have bachelor and master candidates in their groups.

Networking might be experienced and trained by cooperation in international projects, and by giving presentations during national and international conferences. Self-assurance might be achieved by integration of doctoral candidates into the educational programs of the university.

Experiences in entrepreneurship might be prepared by additional courses that are offered to doctoral candidates. However, these courses must not obstruct autonomous acting of the doctoral candidates. Therefore, they must take only limited time as compared to the other duties of the doctoral candidates.

Quality control ought to be introduced for all aspects of the doctorate. Time control is certainly necessary as part of the own project management, but it should also be applied by supervisors. As part of the own project management, a research plan including (soft) milestones might be advisable. This plan should be known not only to the candidate and his or her supervisor but also to at least a second potential reviewer.

A good part of the given suggestions has already been successfully tested by the authors. Response from commerce and industry encourages them to proceed in that way in order to improve the engineering doctorate by specifically supporting the acquisition of the particular skills and competences of a doctor of engineering.

6. CONCLUSIONS

The expectations of which skills and competences a doctor of engineering should have achieved are changing. Doctors of engineering are no longer expected to be only experts in highly specialized fields of research or development; they are rather seen as prospective chief officers in research institutions as well as in commerce and industry, or in administration.

Higher educational institutions must therefore adapt to these needs. It would be highly interesting to find out about differences in these needs in different countries.

Such a survey is being compiled at the moment within an ERASMUS thematic network which is funded by the European Commission [22].

7. REFERENCES

[1] Bologna Secretariat, "About the Bologna Process", Available at http://www.ond.vlaanderen.be/hogeronderwijs/bologna/about/na/about/.

[2] A. Akay, "A Renaissance in Engineering PhD Education", **European Journal of Engineering Education (EJEE)**, vol. 33, no. 4, pp. 403–413.

[3] Woodrow Wilson National Fellowship Foundation, "The responsive Ph.D: Innovations in U.S. Doctoral Education", Available at http://www.woodrow.org/images/pdf/resphd/ResponsivePhD_overview.pdf.

[4] Joint Quality Initiative informal group, "Towards shared descriptors for Bachelors and Masters: Workshop on standards/benchmarks for bachelor en master programmes, Dublin", Available at http://www.jointquality.nl/content/ierland/Shared%20descriptors%20Ba%20Ma.doc.

[5] Joint Quality Initiative, "Shared ‘Dublin’ descriptors for Short Cycle, First Cycle, Second Cycle and Third Cycle Awards", Available at http://www.jointquality.nl/content/ierland/Complete_set_Dublin_Descriptors_2004_1.31.doc.

[6] Commission of the European Communities, "Towards a European Qualifications Framework for Lifelong Learning", Available at http://ec.europa.eu/education/policies/2010/doc/consultation_eqf_en.pdf.

[7] T.J. Shuell, "Cognitive Conceptions of Learning", **Review of Educational Research**, vol. 56, pp. 411–436.

[8] D.C. Leonard, **Learning theories, A to Z**. Westport, Conn: Oryx Press, 2002.

[9] D.A. Kolb, **Experiential learning: experience as the source of learning and development**. Englewood Cliffs, N.J: Prentice-Hall, 1984.

[10] R.M. Gagné, **The conditions of learning**. New York [u.a.]: Holt, Rinehart and Winston, 1965.

[11] R.M. Gagné, and M.P. Driscoll, **Essentials of learning for instruction**. Englewood Cliffs, N.J: Prentice Hall, 1988.

[12] M.H.W. Hoffmann, "An engineering model of learning: Proceedings 35th Annual Conference", in *Frontiers in Education, FIE '05*, 2005, pp. T2C-1-6.

[13] L.W. Anderson, D.R. Krathwohl, and B.S. Bloom, **A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives**. New York: Longman, 2001.

[14] M.H.W. Hoffmann, "Knowledge, Skills, and Competences: Descriptors for Engineering Education", in: *IEEE EDUCON Education Engineering 2010*; Madrid, April 2010, pp T1A-1-7; ISBN 978-1-4244-6569-9.

[15] Engineering Council UK, "Chartered Engineer and Incorporatd Engineer Standard", Available at http://www.engc.org.uk/documents/CEng_IEng_Standard.pdf.

[16] National Society of Professional Engineers, "What is a PE", Available at http://www.nspe.org/Licensure/WhatisaPE/index.html.

[17] acatech, **Empfehlungen zur Zukunft der Ingenieurpromotion:** *Wege zur weiteren Verbesserung und Stärkung der Promotion in den Ingenieur-wissenschaften an Universitäten in Deutschland*. Stuttgart: Fraunhofer-IRB- Verl., 2008.

[18] Soo M., **Doctoral education in the field of engineering**, Center for Higher Education Policy Studies (CHEPS), University of Twente, The Netherlands, 2007.

[19] W.v. Humboldt, and A. Flitner, **Werke in fünf Bänden:** 3rd ed. Darmstadt: Cotta; Wiss. Buchges., 1980.

[20] C. Feller, G. Ellis, and H. Rauen, **Anforderungen and die Promotion im Maschinenbau und der Verfahrenstechnik:** *Ergebnisse einer empirischen Untersuchung*. Frankfurt: IMPULS-Stiftung.

[21] O. Bonnaud, and M.H.W. Hoffmann, "New Challenges for Doctoral Studies in Europe in the Field of Electrical and Information Engineering", in **EUA Bologna Handbook - Making Bologna Work**, E. Froment, J.P.L. Kohler, and L. Wilson, Eds., Berlin, Stuttgart: Raabe Acemic Publishers, 2009, pp. C4.4-4.1 - C4.4-4.24.

[22] “Enhancing Lifelong Learning for the Electrical and Information Engineering Community (ELLEIEC)”, Available at http://tlc.diee.unica.it/elleiec/demo/.