

Towards Transparent, Readable and Comparable Third Degree: Making Doctorate-level Engineering Education a Part of the Bologna Process

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ABSTRACT: *A 4-year PhD programme was introduced in 1999 at the Faculty of Electronics and Information Technology, Warsaw University of Technology, as part of an effort to transform the model of engineering education into a three-cycle study system.*

The curriculum requirements for the new programme, that combines course work and individual research work leading to a thesis, are defined using the credit point system. Another characteristic feature of our programme, quite unique for the system of doctorate-level education at Polish higher education institutions, is its partial integration with the second-cycle (Master) programme. This integration allows for more efficient usage of resources and for reduction of time it takes to receive the PhD degree. It also contributes to an improvement of education quality at the Master level.

Through the flexibility of curriculum and special admission policy, which opens our programme to good candidates who graduated from non-engineering institutions, an opportunity is created for pursuing studies of interdisciplinary character. Our PhD students can complete a part of their education at universities or research centres abroad. This, combined with our alternative PhD programme taught in English, intended for both Polish and foreign students, creates a sound basis for the development of joint degree programmes at the doctorate level.

Our new PhD programme appears suitable to the needs and expectations of candidates and students. Therefore, despite unattractive financial offer, the number of good candidates is quite large and the total number of our PhD students has exceeded 200. Also, the attrition rate has been relatively low; among the students admitted in academic years 2000/01 and 2001/02, the percentage of those who survived the most difficult first two years of study is about 70% - the level that has never been reached before.

1 INTRODUCTION

The doctorate-level education in Europe is very diversified. The highly unstructured model, quite popular in some countries, i.e. leaving candidates to a doctoral degree largely on their own and providing them only with more or less intensive individual tutoring and supervision, is no longer suited to the challenges of modern society and hampers the development of the European Higher Education Area and the European Research Area [1,2]. This is particularly true for some areas of science and engineering, such as information technology or bioengineering, where the number of highly qualified researchers is a key factor that determines the future of our countries and the position of Europe as a whole in the world economy.

The need for more structured doctoral studies in Europe has, therefore, been expressed repeatedly in recent years, in particular in the official documents of the European Commission [3]. Following these opinions, the ministers in charge of higher education who gathered at the Summit in Berlin on 19 September 2003, conscious of the importance of research as an integral part of the higher education system, found it necessary to go beyond the present focus on two main cycles of studies and decided to include the doctorate-level education as the third cycle in the Bologna Process [4]. Although such a solution is not unanimously supported, especially by the engineering community (see, for example, the Communication of CESEAR and SEFI of February 2003 [5]), there is no doubt that the successful development of the Europe of Knowledge requires changes in the model of education at the doctorate level.

2 ENGINEERING EDUCATION AT THE DOCTORATE LEVEL IN POLAND

In Poland, PhD degrees are awarded by individual faculties of higher education institutions and by research institutes. The list of institutions that can award the PhD degree in a particular area is determined by the state-controlled body - the Commission for Scientific Degrees, based on the evaluation of research potential of institutions (mainly, the number of full-time professors).

A candidate for a PhD degree should hold a Master degree (in theory, it is possible to award the PhD degree to a person who does not satisfy this requirement, but in such a case, the procedure is extremely complex and, therefore, very infrequently used in practice). A graduate from the Master programme seeking a PhD degree is faced with the following options:

- a) to pursue a PhD programme offered by a higher education institution or research institution while possibly working somewhere else; a typical PhD programme combines course work and individual research work supervised by a senior member of academic or research staff at the institution that offers the programme;
- b) to take a position of a teaching or research assistant at a higher education institution or research institution and pursue - in parallel with routine and administrative duties - research work under supervision of a senior member of academic or research staff of that institution.

Another possible option - the most difficult one - is to pursue individual research work under supervision of a senior member of academic or research staff of some higher education institution or research institution while working at some other institution (usually full-time and not necessarily in the area related to the work done towards the PhD degree).

Regardless of the selected path, to obtain the PhD degree in the selected field of engineering, the candidate must submit a thesis that is subsequently thoroughly examined by reviewers, pass an examination in the selected field, pass two auxiliary examinations (in foreign language and in some area of humanities and social sciences), and finally publicly defend the thesis.

Until the early 1990's, only a limited number of institutions offered structured PhD programmes. The preferred way to obtain the PhD degree was, therefore, to follow path (b) described above. A change occurred in the mid 1990's, after the Ministry of Education introduced new rules for financing higher education institutions. The key regulation was that the amount of money received by an institution from the state budget strongly depends on the number of students. In the algorithm that was used to determine the distribution of the budget money, various groups of students were assigned different weights, depending on the costs of education in specific fields, and on the level of study. In particular, the basic weight assigned to a PhD student was 5, whereas the weight assigned to an undergraduate student was 1. This way, a strong incentive was created for higher education institutions to develop PhD programmes. Although these rules of financing were abandoned a few years ago, the PhD programmes introduced in the 1990's are still offered.

It might appear that the interest in studying, observed among young people in Poland after the political changes of 1989, and the abundance of opportunities offered to PhD candidates, must have resulted in a sharp increase in the number of PhD students. Generally, this was the case. Since 1990, the total number of PhD students has increased more than tenfold: from less than 2 700 in academic year 1990/91 to more than 31 000 (including more than 7 000 engineering students) in academic year 2002/03 [6].

However, along with visible successes, there have been problems. Several factors have had a negative impact on the number and quality of PhD engineering students, especially in those areas of engineering that contribute most to the development of the information society:

- The prospects of high salaries in business-related areas have discouraged the most capable young people from seeking a scientific career in engineering.
- An obvious consequence of a significant increase in the total number of high school graduates admitted to engineering programmes has been a large diversification in their educational background and capabilities. This quite frequently has led to the relaxation of degree requirements, especially at universities that followed the traditional model of engineering education - the 5-year programme leading to the Master degree. This, in turn, has had a negative impact on the quality of candidates for PhD studies.

- In the mid and late 1990's, the graduates from the Master programmes in computer science and engineering, telecommunications, and related areas were offered attractive jobs at mobile telephony operators and other national and international high-tech companies.
- The process leading to the PhD degree in engineering has traditionally been quite long. As the MSc programme is usually unrelated to the research work carried out at the PhD level, this work normally takes 5-7 years (most recipients of the PhD degree in engineering are in the age group of 31-35 [6]). With generally poor financial status of PhD students, this is not a very attractive prospect for gifted young people.
- Low stipends and limited extra support from research grants force most PhD candidates to take full- or part-time jobs outside the university. Obvious difficulties in sharing time between job-related activities and research work result in a large number of resignations and dismissals from the PhD programmes.

Under these circumstances, to meet the needs of the modern society, the system of PhD education must be both attractive for candidates and efficient (providing reasonable completion rate). In this paper, we show how this challenge has been dealt with at our institution - the Faculty of Electronics and Information Technology, Warsaw University of Technology.

3 NEW MODEL OF DOCTORATE EDUCATION AT THE FACULTY OF ELECTRONICS AND INFORMATION TECHNOLOGY

The Faculty of Electronics and Information Technology is the largest teaching and research centre at the Warsaw University of Technology. The Faculty has more than 4000 students. They are served by 280 members of academic staff (250 of them hold the PhD degree) and 170 members of technical and administrative staff. More than 1900 computers are used by students and staff for education, research and administration.

PhD programme as part of the restructured study system

The restructuring of the PhD education at the Faculty of Electronics and Information Technology has been a part of the long-term process of reforming the study system [7-11]. It started in academic year 1994/95, when the two-cycle system (Bachelor-Master), with an option for the long Master programme was introduced (all students admitted to the Faculty before 1994 pursued a 5-year programme leading to the MSc degree). In academic year 1999/2000, the third-cycle (PhD) programme was offered.

The organization of the restructured study system at the Faculty is shown in Fig. 1. The system includes:

- first-cycle studies: a 4-year programme (240 ECTS points) leading to the degree of “inżynier”, equivalent to BSc,
- second-cycle studies: a 2-year programme (120 ECTS points) leading to the degree of “magister inżynier”, equivalent to MSc,
- third-cycle studies: a 4-year programme (240 ECTS points) leading to the degree of “doctor”, equivalent to the PhD.

A student who enters the second-cycle studies with a Bachelor degree (obtained at the Faculty or at some other institution) can transfer some credit (up to 60 ECTS points) received for courses taken during the first-cycle studies. This essentially means that in most cases 5 years is sufficient to receive the MSc degree. Likewise, a part of credit received for advanced courses taken during the second-cycle studies can be transferred to the PhD studies, as will be discussed in more detail below.

Curriculum requirements

The curriculum requirements for the new PhD programme in Electronics and Information Technology are defined using the credit point system (it might be worth mentioning that only 12.9% of European universities apply a credit point system at this level of education [1]). These requirements are shown in Table 1.

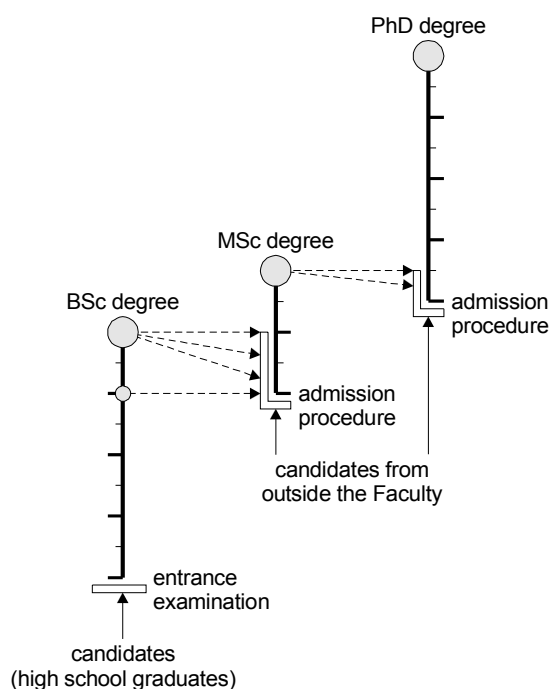


Figure 1 - Study system at the Faculty of Electronics and Information Technology

Table 1. Curriculum requirements for the PhD programme

	ECTS points required	maximal transfer
courses in humanities and social sciences	6	4
courses in engineering	8	8
advanced math and science courses	12	6
advanced specialization-oriented courses	12	6
advanced courses (free electives)	18	6
PhD seminar	14	-
PhD research	140	-
<i>total</i>	<i>210</i>	<i>30</i>

As can be seen from Table 1, individual research work leading to the PhD thesis is the major component of the programme. This work should start in the very first semester. Each semester the student must submit a report that documents his/her progress in research. This report is evaluated by the student's advisor and by the Director of the PhD Programme. There are special requirements regarding publications - the student is expected to publish at least one paper during the first year of study, and another paper (in an international journal or at an international conference) during the second year of study.

The course work is intended to provide the student with theoretical background in the selected area and extend his/her knowledge of advanced concepts in engineering. A flexible approach is used. The students can take courses at various faculties of our university or at other higher education institutions in Poland and abroad. Participation in international summer schools and similar activities can also be considered as a partial fulfilment of the curriculum requirements. However, for each course taken outside the Faculty, a short documentation must be provided that proves its adequate level and quality, so that the decision to transfer credit earned outside the Faculty could be taken by the Director of the PhD Programme.

The 210 ECTS points in the last row of Table 1 correspond to 7 semesters of studying. The last, 8th semester is thought of as a time when the candidate prepares the final version of the thesis, prepares for and takes PhD examinations and prepares for the public defence of the thesis. The minimum requirement for the completion of the PhD programme is to submit the thesis approved by the advisor; reviewing process and the defence may take place later (after the programme is formally completed).

Integration with the MSc programme

A distinguishing feature of our PhD programme is its partial integration with the second-cycle (MSc) programme. Such an integration is normal in many countries, but in Poland is very uncommon. PhD programmes offered at Polish higher education institutions are traditionally almost entirely separated, with regard to both curriculum and administration, from the Master programmes; in particular, doctorate studies are usually supervised by a vice-rector responsible for science, and not for education. This is a consequence of legal regulations: the organisation of PhD studies is regulated by the Act on Scientific Title and Degrees and not by the Act on Higher Education. (In line with the latest developments in the Bologna Process, in the draft of the new Law on Higher Education, PhD programmes are considered as third-cycle studies and a part of the higher education system.)

The integration of the PhD programme with the MSc programme has the following aspects:

- The MSc and PhD programmes are both offered in the same four fields (areas): Automatic Control, Informatics, Electronics, and Telecommunications. The names of these areas correspond exactly to the names of scientific disciplines in which - according to the law - the PhD degree can be awarded.
- To satisfy the curriculum requirements for both the MSc and PhD programme, some number of credit points must be earned by taking courses from a special group of advanced courses (math and science, specialization-oriented, and elective courses). More than 60 such advanced courses are now offered.
- A part of credit received for courses taken during the second-cycle studies can be transferred to the third-cycle studies; all together, an equivalent of up to one full semester of study can be transferred (see Table 1). Such a transfer leaves the PhD student with more time for research work and makes it possible to complete the programme earlier.

The integration of the MSc and PhD programmes through a common offer of advanced courses allows us to overcome the problem encountered at many other institutions that rely on a separate course offer for the PhD students. As the number of PhD students is quite limited (significantly lower than the number of MSc students) and, for economical reasons, it is impossible to run a large number of courses taken by only a few students, the number of PhD-level courses must be low. This obviously has a negative impact on the flexibility and attractiveness of the PhD programme.

Academic regulations

The student has a lot of flexibility in distributing the course load during the period of studies. However, for each semester, minimal requirements on the number of courses (taken from the beginning of the study period) are set. The student report on his/her progress in research is also examined each semester. The student who does not satisfy the requirements is dismissed from the programme.

An essential point during the study period is associated with the formal initiation of the PhD track. This decision is taken by the Faculty Council after examining the record of the candidate (in particular, the list of his/her publications) and upon recommendation of the advisor who should declare that the work on the thesis is completed in at least 50%. It is recommended to take this formal step by the end of the 5th semester of study.

In practice, it happens quite often that the formal initiation of the PhD track is delayed and the 4-year period in which the thesis is to be submitted is not sufficient. Then, the student can apply for a one-year extension of the study period. The student who does not submit his/her thesis on time - within 4 years or, when the extension is granted, within 5 years - is dismissed from the programme. This means that he/she loses the student rights (in particular, the stipend), but - upon acceptance of his/her advisor - can continue the work towards the PhD degree on a less formal basis.

Other characteristics

Another feature of our PhD programme, quite unusual for the traditional doctorate-level education in Poland, is that admission criteria are based exclusively on achievements, disregarding to a large extent the field in which the Master degree has been awarded. Each candidate for the PhD programme is requested to look for and eventually find his/her future advisor and to specify his/her research plans. To help the candidates, a list of 70 Faculty's professors and associate professors - potential advisors, with characteristics of their professional activities and interests is available. An opinion of the future advisor on the candidate is one of the key factors taken into account by the PhD Admission Committee.

Our PhD students have many opportunities to get international experience:

- some students pursue their research work as part of international research projects, e.g. projects supported by the EU Framework Programmes;
- some students spend a part of their study period abroad; students mobility is based on international cooperation agreements between our Faculty and other institutions; quite frequently, students participation in research projects carried out at foreign universities or research institutions is a result of informal contacts and recommendations of their advisors;
- a special Dean's fund has been established to support the participation of PhD students (especially, first- and second-year students) in international conferences at which they present their papers;
- an international workshop intended primarily for PhD students is organized each year in Poland by one of the departments (institutes) of our Faculty; this very low-cost event, supported by the IEEE and included in the official calendar of events of this organization, attracts many participants from our country and from other Central European countries.

4 EXPERIENCE AND OBSERVATIONS

Our experience associated with the functioning of the new PhD programme should be discussed in the context of the whole process of restructuring the study system at the Faculty of Electronics and Information Technology. The new system has proven quite attractive to candidates and students - a significant increase in the number of high school graduates applying for studies at the Faculty has been observed in recent years [11]. This, in turn, has had a positive impact on capabilities of the students and on qualifications of those who graduate with the MSc degree - the primary candidates to our PhD programme. Thus, the PhD programme appears to benefit from the changes made in BSc- and MSc-level education.

The data characterizing our new PhD programme are shown in Fig. 2, Table 2 and Table 3. In Fig. 2, the growth of the number of students is shown (this graph does not account for students who pursued the "old" PhD programme; i.e. students admitted before 1999). Two points on the curve associated with each year correspond to the groups of students who started their programmes in the first and second semester of a particular academic year. The same convention is used in Table 2 and Table 3; for example, symbol 2000.1 corresponds to the group of students who started the programme in the first (fall) semester of 2000/01, whereas symbol 2000.2 to the group who started the programme in the second (spring) semester of 2000/01. Table 2 shows the process of attrition, i.e. how the initial size of the student group (number of admitted candidates) was decreasing over time due to resignations and dismissals. Table 3 illustrates the progress towards the degree. It shows, for the various groups of students, when the formal procedure of initiation of the PhD track took place and when the thesis was submitted.

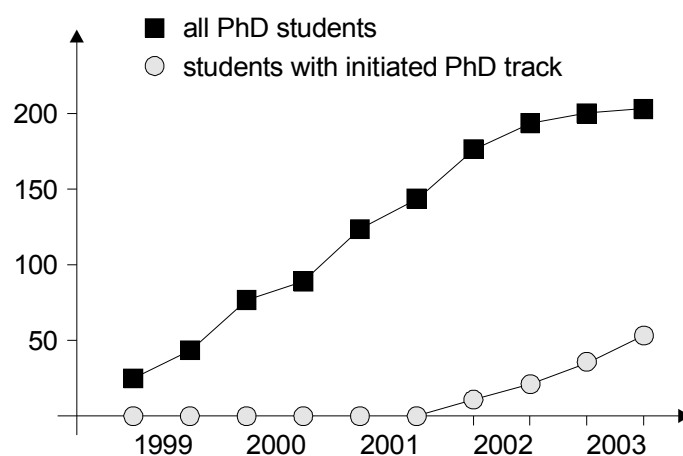


Figure 2 - Number of students in the new PhD programme

Table 2. Percentage of admitted students staying in the programme

beginning of studies	number of admitted candidates	percentage of admitted students staying in the programme			
		after 1st year	after 2nd year	after 3rd year	after 4th year
1999.1	25	68.0	52.0	48.0	48.0
1999.2	22	72.7	59.1	40.9	40.9
2000.1	41	80.1	78.0	70.7	-
2000.2	19	68.4	57.9	52.6	-
2001.1	46	78.3	71.7	-	-
2001.2	30	80.0	63.3	-	-
2002.1	46	78.3	-	-	-
2002.2	28	67.9	-	-	-
2003.1	26	-	-	-	-
2003.2	20	-	-	-	-

Table 3. Progress towards the degree

beginning of studies	percentage of admitted students having the PhD track initiated by the end of			percentage of admitted students who submitted the thesis by the end of		
	5th semester	6th semester	8th semester	7th semester	8th semester	9th semester
1999.1	0	44.0	44.0	0	0	4.0
1999.2	0	13.6	22.7	0	0	-
2000.1	14.6	41.5	48.8	4.9	-	-
2000.2	5.3	26.3	-	-	-	-
2001.1	32.6	-	-	-	-	-

The following observations can be made:

- Since the introduction of the programme, the number of admitted candidates has been quite large. In 2001 and 2002, we admitted about 75 candidates each year. The number of candidates admitted in 2003 was lower because of the more restrictive stipend policy and resignations of those candidates who had no chance to receive a stipend. As the first group of our PhD students (admitted in the fall semester of 1999) reached their last, 10th semester of study (including the extension period), the constantly growing number of students has approached the saturation level – slightly more than 200 (see Fig. 2). This accounts for more than 16% of PhD students at the Warsaw University of Technology - a significantly larger fraction than the contribution of the Faculty to the total number of all BSc and MSc students at the University which approaches 12%. The impact of our programme is even more visible if we consider all engineering oriented higher education institutions in Poland. Our Faculty accounts for about 1% of the total number of BSc and MSc students and for almost 3% of the total number of PhD students at these institutions.
- Slightly more than 50% of admitted students survives until at least 4th year. The highest attrition rate occurs during the first year of study. This is mostly an effect of resignations and dismissals of those who try to combine the PhD studies with full-time employment.
- Among those who are in the 4th year of the programme, a large majority have the PhD track initiated. For them, the likelihood of a success (receiving the PhD degree no later than one year after leaving the programme) is rather high - the earlier experience shows that it is above 80%. Therefore, we can expect that about 40% of those admitted to our programme will end up with the PhD degree.
- It appears that it is quite difficult to complete the programme (submit the thesis) in 4 years. Among 20 students admitted in October 1999 and still staying in the programme (on extension), nobody was able to accomplish that. Only one of these students submitted his thesis during the 9th semester. We predict, however, at least 12 more thesis submissions by the end of the 10th semester of study.

Although the history of our new PhD programme is not long, a number of positive trends can already be observed.

- The attrition rate is diminishing. In particular, the percentage of students who survived the first two years of study has increased from 55.3% among those admitted in academic year 1999/2000 to about 70% among those admitted in 2000/01 and 2001/02.
- An impressive improvement can be observed regarding the period of time needed to formally initiate the PhD track. None of students admitted in 1999/2000 was able to initiate the PhD track as recommended, i.e. by the end of the 5th semester. As a consequence, as was stated earlier, none of these students was able to submit the thesis on time (by the end of the 8th semester). Among students admitted in 2000/01, 11.7% initiated the PhD track by the end of the 5th semester and two of them submitted their theses by the end of the 7th semester. For students admitted in 2001/02, the percentage of those who initiated the PhD track as recommended increased to 32.6% (students admitted in February 2002 are not counted because they have not completed their 5th semester of study yet). Clearly, the earlier the track is initiated, the higher the likelihood of a successful completion of the thesis on time.

Another positive trend is a growing diversification of our candidates. Through the flexibility of curriculum and special admission criteria, we have created an opportunity for pursuing studies of interdisciplinary character. The topics of the two recently submitted theses were related to DNA computing (a part of research was done at the Warsaw University in the group working on genetics) and to e-economy, specifically micropayment protocols in mobile telephone networks. An opportunity to work in an interdisciplinary environment attracts increasingly more good PhD candidates who graduated from other institutions, not necessarily related to engineering - in particular, from arts and science oriented universities. Among candidates admitted in September 2003, more than 25% were graduates from other institutions. It might look normal, but it should be noted that for the last 30-40 years, the traditional model of a successful academic career in Poland has been to complete an MSc programme, get a job at the same institution, and stay there until retirement, receiving on the way a PhD degree, a DSc degree (habilitation) and the title of Professor.

5 CONCLUSION

A 4-year PhD programme, combining both course work and individual research work, was introduced at the Faculty of Electronics and Information Technology in 1999, as part of the three-cycle study system, long before the ministers in charge of higher education decided to include the doctorate-level education in the Bologna Process.

This new PhD programme has some features that are quite unique for the system of doctorate-level education in Poland. These include:

- integration with the MSc programme,
- flexible curriculum requirements defined using the credit point system,
- an admission procedure open to candidates with non-engineering background.

The new programme appears suitable to the needs and expectations of candidates and students. Therefore, despite unattractive financial offer (only about 50% of admitted students receive a stipend in the amount of 200-250 euro per month), the number of good candidates is quite large and the total number of our PhD students has exceeded 200. Also, the attrition rate has been relatively low; among the students admitted in academic years 2000/01 and 2001/02, the percentage of those who survived the first two years of study is about 70% - the level that has never been reached before.

Through the flexibility of curriculum and special admission policy, we have created an opportunity for pursuing studies of interdisciplinary character. Therefore, we are able to attract increasingly more good candidates who graduated from other institutions, not necessarily related to engineering.

The flexibility of curriculum defined using the credit point system makes it possible for our students to complete a part of their programmes at universities or research centres abroad. This, combined with the alternative PhD programme taught in English, offered at our Faculty as part of the three-cycle studies intended for both Polish and foreign students, creates a sound basis for the development of joint degree programmes at the doctorate level - considered as one of the most attractive features of the European Higher Education Area [1].

A partial integration of the new PhD programme with the MSc programme allows for the better usage of resources and for a reduction of time it takes to receive the PhD degree. It also contributes to an improvement of education quality at the Master level. The MSc curriculum contains now more advanced courses and is more research-oriented. This, of course, has a positive impact on the qualifications of candidates for the PhD studies.

Having, unlike other Polish institutions of engineering education that started their reforms later, a 10-year experience with the three-cycle system (Bachelor-Master-Doctor), including a 5-year experience with the new PhD programme, we believe (and have indications) that the number of recipients of the PhD degree at our Faculty will steadily increase in the coming years. This is essential because with the traditional model of PhD education, based on intensive individual tutoring and supervision, we were not able to produce a sufficient number of doctors, especially in those areas of engineering and interdisciplinary studies that are crucial for the development of the information society. We also believe that our effort contributes to eliminating divergences in the provision of doctoral studies across Europe. It can be considered as an answer to *a need for a transparent, readable and comparable „third degree”* [2] - currently, one of the main goals of the Bologna Process.

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