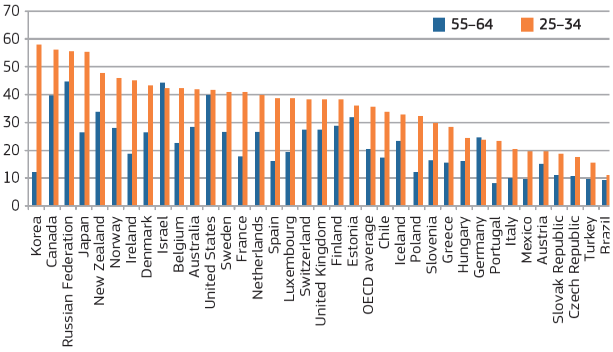
Improvement of Academic and Research Standards of Higher Engineering Education in Light of Bologna Process

L. Szentirmai and L. Radács
University of Miskolc, Department of Electrical and Electronic Engineering, Miskolc, Hungary
elkerika@uni-miskolc.hu elkrad@uni-miskolc.hu

***Abstract* -- Today Europe has some 4000 institutes of higher education in 45 countries; 35% provide graduates in engineering. All institutes contribute to the creation of a knowledge-based society which is rooted in higher education, innovation and research. Europe's added value would be based on the new knowledge generated within the European Research Area. The ideal mechanism for knowledge creation and transfer is when the best universities will become the gold standard i.e. the excellence. Thus priority will be given to academic and research standards and the Bologna process assists in the implementation of this trend. University of Miskolc and its relevant Departments are striving for excellence by four new Research Centers in Engineering. They improve both academic and research standards and in such a way contribute to knowledge society.**

I. INTRODUCTION

The future of the strong, new Europe is building up by higher education. Today, Europe has some 4000 institutes of higher education in 45 countries; around 35% are dedicated to engineering either as independent technical university or separate faculty/school. 1000 of theirs are genuine "universities" on the basis of criterion to award doctoral, PhD or equivalent degrees. All these 4000 institutions with 17 million students, of 1.1% belong to PhD programs, 435 000 researchers,



Source: OECD 2010

Figure 1. Percentage of population with higher education in age groups 25-34 and 55-64

The described work was carried out as part of the TÁMOP – 4.2.1.B-10/2/KONV-2010-0001 project in the framework of the New Hungarian Development Plan. The realisation of this project is supported by the European Union, co-financed by the European Social Fund.

1.5 million academic, administrative and technical staff – produce roughly a million mathematics, science and technology graduates and about 90 thousand PhD degree-holders a year. In the EU 23% adults (2012) have achieved higher education (Figure 1) and by 2030 this rate as envisaged will be 40%.

In order to improve the mutual recognition of university programs and degrees, in Bologna, the famous Italian University City, Ministers of Education from 29 European countries (later on other European countries joined) signed in June 1999 the "Bologna Declaration" whereby they committed to establish the European Higher Education Area (EHEA).

Arriving at the conclusion, the ideal of the European university is the open, digitally networked, knowledge institution working in co-operation with industry and society. Some further clustering of universities is expected to gain leadership in one or more emerging fields.

All in one, striving for excellence is the only choice Europe has. This needs the improvement of academic and scientific research standards. The ideal mechanism is when the EU institutions will become the "gold standard" to which all may aspire, but only the best succeed.

This paper deals with the endeavors for excellence European universities of technology have to reach furthermore it presents the efforts of the University of Miskolc and the Department of Electrical and Electronic Engineering in the field of academic and scientific research standards.

II. EUROPEAN RESEARCH AREA

A. Origin and contribution to knowledge society

A knowledge-based society [2] and [3] rooted in higher education, innovation (i.e. the share of inventions that actually reach the market) and research (knowledge triangle).

The European Research Area was made up of two components:

(i) a "large European research market" where researchers, knowledge and technology would circulate freely; and

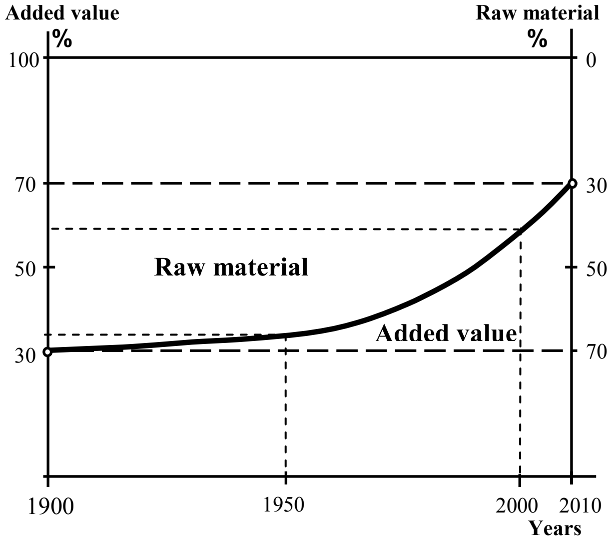
(ii) an area for the coordination of national activities, initiatives and policies. The creation of the European Research Council (ERC) and the cautious development

978-1-4673-5122-5/12/$31.00 ©2012 IEEE

of a European policy for supporting infrastructures show that there is a third dimension: the European Research Area is also (iii) an area for the implementation and funding of Europe-wide initiatives.

"While technological progress creates the jobs of tomorrow, it is research that creates the jobs of the day after tomorrow". (Citation comes from the Communication of the European Commission, 2000).

In the early 20th century 70% of a product in the world originated from raw material, and by 2011, 70% is added-value (Figure 2).



Source: OECD Statistics. Diagram designed by the authors

Figure 2. Ratio of added value to raw material of a product in the world in percentage

B. *Achievements of the European Research Area*

The Triad (the EU, the USA and Japan) are dominant in scientific research with knowledge creation on world-wide indicators (Tables I and II).

TABLE I.

COMPARISON INDICATORS OF SCIENCE AND TECHNOLOGY BETWEEN EU-27 AND ITS COUNTERPARTS (THE TRIAD)

Indicators for competitiveness	*EU-27*	*USA*	*Japan*
RTD effort, billion Euro per annum	214	274	118
Number of researchers (Full-time employed, FTE) in thousands	1301	1388	710
Number of researchers (FTE) per 1000 workers	5.6	9.3	10.7
Intensity of research effort in percentage of GDP	1.85	2.61	3.39
Share of private sector financing in percentage	55	65	77
Share of publications worldwide in percentage	37.8	31.5	7.9
Share of worldwide patents registered in the Triad	30.9	33.1	18.3

Source: European Commission Report 2008, structured by the authors

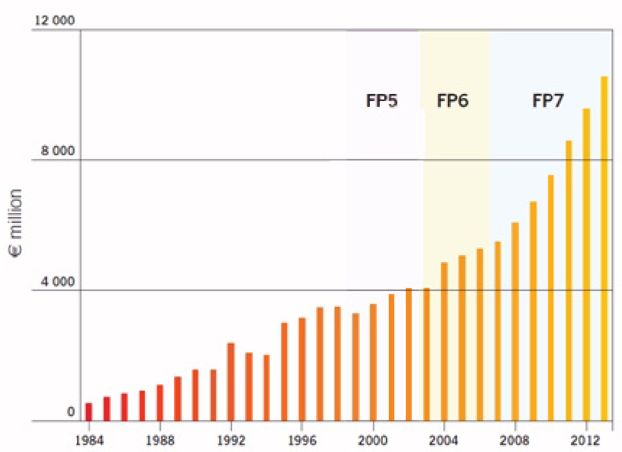
The importance of scientific research and technological development in the European Union is demonstrated by the research frameworks budget (Figure 2).

TABLE II.

PRINCIPAL SCIENCE AND RESEARCH INDICATORS OF COMPARISON BETWEEN THE EU, USA AND JAPAN

Indicators	*EU-15*	*USA*	*Japan*
Number of researchers per 1 000 persons employed	5.5	9.0	9.7
Scientific articles published as percentage of those published worldwide	38.3	31.1	9.6
Number of scientific articles per million inhabitants	639	809	569
Patents in the Triad per million inhabitants	30.5	53.1	92.6
High-tech products as percentage of total industrial exports	19.7	28.5	26.5
Share of global high-tech industrial exports	16.7	20.0	10.6

Note: the Triad refers to the three markets: EU, USA and Japan.
Source: European Commission, OECD



Sources: Annual Reports of European Commission

Figure 2. Scientific research Framework Programs budget in current prices (1984-2013)

TABLE III.

PROJECTED IMPACT OF THE 7TH SCIENTIFIC RESEARCH FRAMEWORK PROGRAM IN 2030 (NEMESIS-BIS)

Projected development of major trends	*Doubling of Seventh Framework Program budget and subsequent moderate growth*	*Doubling of Seventh Framework Program budget and subsequent strong growth*
Increase in GDP (%)	+0.45 to +0.69	+0.95 to +1.66
Job creation	+418 000	+925 000
Of which research jobs	+40 000	+214 000
Increased research intensity (as % of GDP)	+0.059	+0.228
Increase in extra-European exports (%)	+0.64	+1.57
Reduction in extra-European imports (%)	-0.27	-0.88

Source: European Commission

Table III presents figures for 2030 obtained from a sophisticated economic model known as "Nemesis-bis" (In Greek mythology, Nemesis was the spirit of divine retribution against those who succumb to hubris –

arrogance before the gods. The Greeks personified vengeful fate as a remorseless goddess: the goddess of revenge.).

Unlike a "business as usual" scenario (maintenance of a budget equivalent to the present budget), this compares the forecasts of a number of indicators in the case of two hypotheses: that of a doubling of the 2007-2013 budget followed by a return to moderate increases, and that of a doubling of the budget followed by other major increases for subsequent strong growth.

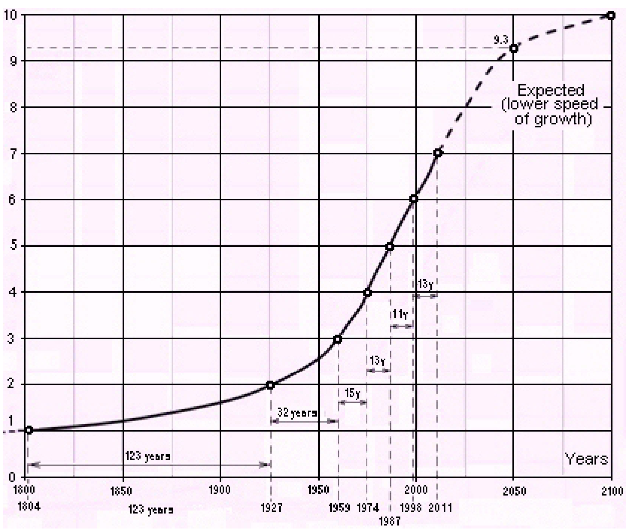
C. *Europe's strengths and weaknesses in scientific research*

European scientific publications may be more numerous, but they are not the most cited, and that is the criterion that traditionally measures the true impact of scientific research. Of the 10% most cited publications, a clear majority are US publications. The reason for this is the lack of thematic specialization on the part of European research. While the EU puts a respectable performance in all fields, it is dominant in none of the most dynamic sectors. The United States dominates in the biomedical field and Japan is the undisputed leader in material sciences; the EU does a little of everything.

It is these NBIC (Nanotechnologies, Biotechnologies, Information and communication technologies, and Cognitive science) that are crucial for the future of the knowledge economy. In these fields, applications are close to, indeed often inextricable from, the production of new knowledge.

A new, holistic way of thinking is required as technological answers alone are not the end-solution to a given problem. Science and research have to look at the systematic arrangement of any action rather than merely the localized gain.

Europeans need to provide an ERA-wide marketplace for innovation that is free, open to all comers, and characterized by a more harmonious partnership between the public and private sector.



Source: United Nations (2011)
Diagram designed by the authors

Figure 3 World's population increase in billions 1800-2100

Europeans need to provide an ERA- wide marketplace for innovation that is free, open to all comers, and characterized by a more harmonious partnership between the public and private sector. Europeans will need to harness their talent much better to solve the Grand Challenges of our age The expansion of the world population from 6 to 9 billion (Figure 3) will intensify global competition for natural resources, and put pressure on the environment.

The financial crisis over the world call into question the production, consumer, living, travel, health, and other habits [4]. Europe's weaknesses in scientific research and technological development are worthy of note: the Achilles' heel is that the research universities, though often prestigious, are underfunded (the EU spent 1.1% of GDP on higher education, compared with 2.6% in the US – 2008). Europe has a crowd of innovation clusters – more than 2 000 – but many are too small to matter economically or scientifically at the global level.

III. Improvement of Academic Standards

A. *Brief history of universities*

Association of American Universities at early 20th century stated: "what defined a university was the offering of graduate work, and that what completed it, in essence as well as in time, was the granting of doctor – PhD – degrees." This declaration was reaffirmed by several societies and the European Union as well.

The origin of universities goes back to 1600 years ago, and on Egypt's shores, the Library of Alexandria (Bibliotheca Alexandrina) catalogued 700 000 listed and classified manuscripts, becoming the world's first higher education institution, or some authors say, the first university in the world.

In the civilized world it is generally accepted that the university as we know it was conceived during the Middle Ages. At first the collective term "studium" or "studium generale" was used, as Latin was the language of academe. One source has traced these terms back to 1233. Over time, the institution that took shape began to be called a "universitas", which described one single body of students and academics.

Two higher education institutions that rose to prominence in the Middle Ages were situated at Bologna and Paris. These institutions are generally identified as the original universities, with the university at Bologna forming around 1158, and the university at Paris sometime between 1150 and 1170.

Slowly, the university concept spread across Europe. Some of the earlier institutions were established about as follows: 1167 Oxford, in what we now call England; 1212 Palencia, Spain; 1224 Naples, Italy; 1290 Coimbra, Portugal; 1347 Cologne, Germany; 1348 Prague, Czech Republic; 1364 Cracow, Poland; 1365 Vienna, Austria; 1411 St Andrews, Scotland; 1425 Louvain, Belgium; 1459 Basel, Switzerland; 1572 Leiden, Netherlands. By the early sixteenth century there were 79 universities in Europe.

By the fifteenth century the university was a recognized institution with a concern for its autonomy vis-à-vis papal interference, with a supranational character and with concerns, customs and ceremonies recognizable in the twentieth-century institutions.

As an indication of the magnitude of these developments there were 10 000 university students in Bologna at the beginning of the 13th century and at Paris was estimated to have had 30 000 students in 1287.

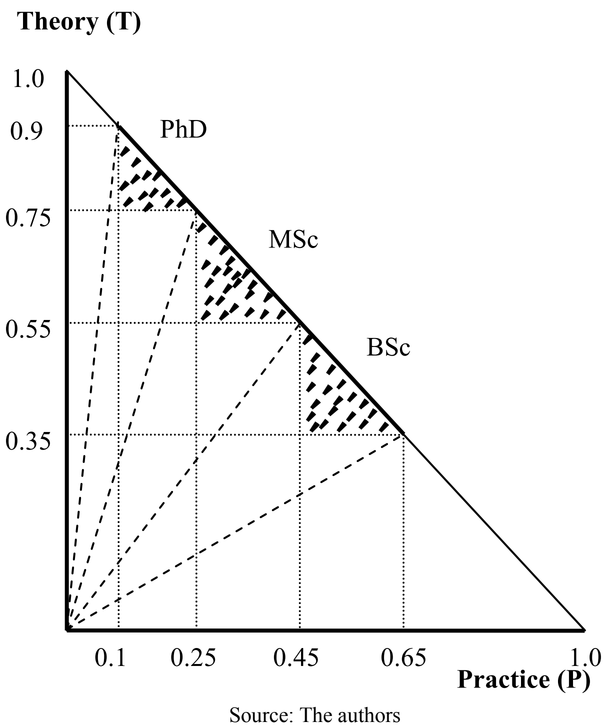
The most significant change to take place after the universities were established throughout Europe was brought about by Wilhelm von Humboldt (1767-1835) whose ideal was the research university.

B. Bologna process implementation in higher engineering education

A university is a "community" of teachers and students, who share questions and answers, learn from each other and, together, search for new knowledge and new answers to new (and old) questions – it is a knowledge centered university [5].

The vital difference between the three higher engineering education cycles in the Bologna process is the theory *T* to practice *P* ratio *T/P* which is dedicated to their time indicated in the curriculum [6]. Thus, this *T/P* ratio defines the professional rank or hierarchy of institutions, higher *T/P* indicates theory-intensive cycle. The total time is counted 1.0 in per unit, thus $T + P = 1.0$ at all engineering curriculum while integrating all basic and applied/frontier science and practice courses needed for graduation (Figure 4).

University of Miskolc experience is that students who have been participating in national and international conferences and received higher ranks from the Hungarian Engineering Institutions for their diploma theses have deeper knowledge in their respective engineering field.



Source: The authors

Figure 4: Higher engineering education cycles in theory-practice domain in per-units. One sign symbolizes one student

C. Universities in the strong new Europe

Europe has the resources of talent and ideas required. With the accession of 12 new members to the EU in less than a decade, the scale and scope of the new Europe has suddenly enlarged. These new members are a special challenge: an untapped pool of talented young people and long University traditions, but by and large an institution infrastructure impoverished by decades of under-investment and in some cases old-fashioned management.

A young graduate will be able to earn a degree in one country and easily move to another to work and teach; indeed, a growing population of researchers will earn PhDs with a truly European dimension, obtained by working in more than one Member State (Euro-PhDs).

It is widely agreed that industry requires (and will continue to do so) a large number of engineers of both BSc and MSc types, in many countries more of the "applied" (i.e. short-cycle) kind than of the other. This fact can be attributed to the rapid development and wide range of new technologies in modern industry. This development has created the need for professionals with the skills and knowledge needed to take advantage of the new technologies, both for current use in the manufacturing process, as well as for the development of new products. The growth in importance of enterprises in the service sector has also contributed to change the overall picture, giving a greater importance to Information and Communication Technologies (ICT) in both "short" and "long" cycles. Further reasons for stimulating an updating of curricula are the growing relevance of basic financial/economic constraint and the international dimension aspects, mainly the need for foreign language skill, but also cross-cultural competences, all are crucial for students.

Students of the EU should be educated to think and manage internationally strengthening European dimension. Therefore, EU universities must attract the brightest brains from around the world, and EU markets the world class competitors; a global university area requires "brain circulation".

Universities' core mission will be therefore to educate graduates and to ensure they are equipped to engage in the process of new knowledge creation and the dissemination and application of knowledge. The speed of innovation will increase affecting social and economic processes; they have to be proactive to plan future scenarios.

Europe's past failures at innovation are true, thus a robust whole-business model for researchers and industrialists and an integrated innovation system in order to strengthen the "put-through" capacities are needed [4]. When large international companies look for a site a research facility, they look not only for major markets, but also for a strong research and competence base. Yet to date, the fact was ignored that proximity of competences matters.

A new positive example emphasizes the link between the proximity of competences and strong research. Daimler Benz, multinational German car industry erected a new unit close to Kecskemét, mid-Hungary city and promoted a strategic partnership with the nearby Polytechnic to start with dual engineering training in the field of motor vehicle manufacture (2012). Around 25 students each year will be attending lectures, doing laboratory works and learning in the school for 24 weeks. During the other 24 weeks they are carrying out engineering work in the factory. After graduation all diploma-holders can enter the world of work at Daimler Benz there (customized education).

The "fifth freedom" – the freedom of knowledge across borders within the EU – will become integrated into the existing rights of people, capital, services and goods to move freely. By 2030 an open, fair, genuine single market for innovation will pull new ideas, talent and investment from around the world [2].

Higher engineering education institutions can, and they should, actively take responsibility for being an instrument for the regional innovation policy. Innovation and knowledge management are to solve the same problem, the need of the industry to develop strategic co-operation with universities in order to be able to respond to challenges of the global economy. And those regional systems, the intellectual capital ones, can be considered as the regional elements of a national concept, the knowledge society. This is the environment where the "knowledge universities" must operate. Several attitudes are identified; the institutional attitude based on the majority attitude of its members can be listed as academic, classical, social, project oriented, entrepreneurial and/or innovative.

The Knowledge University is a complex concept, it is an attitude towards an active innovation policy which is based on a permanent well-functioning co-ordination inside the university focusing on the four basic products as research, technological development and innovation, continuing education, entrepreneurial attention and employment services. Professional leadership using the best methods of business and innovation management is an essential success factor of modern universities.

As part of the third mission, university needs to be organizer of innovation policy activities in society in general and in the region where the university is working in particular.

IV. IMPROVEMENT OF RESEARCH STANDARDS

A. *Striving for excellence by four new engineering research centers at University of Miskolc*

The strategic objective of University of Miskolc (UM) is to become internationally recognized and competitive research University in the European Higher Education Area, to enforce the rival position by the rise of innovation potential and to increase competitiveness of graduates. Its annual income coming from solid innovation activities has doubled since 2010 [7].

UM develops its education, training and service processes based on the operation of four Centers of Excellence and concluded in the following renewals: • scientific achievements will be interwoven with the teaching and indirectly the education structure, then • the quality of PhD Schools will be improving. • New competences created by customized education based on research activities will be transferred to the players of economy and • the income coming from research and technological development service along with four new projects output will be getting higher.

The Operative Program for Society Renewal (in Hungarian: Társadalmi Megújulás Operatív Program – TÁMOP) working within the framework of the New Hungarian Development Plan (in Hungarian: Új Magyarország Fejlesztési Terv) awarded Hungarian Forints (HUF) 2000 million to the University of Miskolc, based on its successful application with the basic target to improve the quality of higher engineering education or in other words to striving for excellence.

The objective of the project is • to contribute to the step-up attractiveness of UM through the higher degree of quality assurance and • to help by the project's implementation the economic and social modernization of the North-East Hungarian region. To serve this objective UM is striving for the creation of intellectual capacity, "a critical mass", needed for research, technological development and innovation carrying out on international scale in strategic areas by the new Centers of Excellence [8]. Research infrastructure development needed for the successful implementation of the project will be provided by another joint project.

For the young researchers – PhD candidates and MSc students – with the provision of scientific leaders of high caliber and research infrastructure the project puts direct impact on the scientific quality of respective PhD Schools, the provision of talented students and the new generation of researchers. The Strategic Board of Experts assists in the positioning and recognition of research teams in the large-scale professional and scientific world in the designated strategic fields.

These Centers are working in harmony and create all requirements needed to keep the young researchers within the University circle or in other words, to carry out brain circulation and prepare the new generation of academics and researchers suitable for the ever-changing world.

The Centre of Excellence on Sustainable Natural Resources Management focuses mainly, among others, water resource management, energy economy, efficient use of natural resources, soil and arable land as well as geo-informatics.

The Centre of Excellence on Applied Material Science and Nano-technology has the objective to apply, even further develop up-to-date scientific methods and processes and gain new experiences on the research areas of material science and material-informatics.

The Centre of Excellence on Mechatronics and Logistics particularly deals with re-organization of material- and product-flow and assembly processes in the most optimistic way. By the development of latter-day technologies the opportunity opens up the door to create new systems and processes meeting the relevant requirements.

The Centre of Excellence on Innovative Mechanical Engineering Design and Technology needs researchers qualified for the development and analysis of design algorithm, product routes and innovative material technology.

B. Research standards progress – Department of Electrical and Electronic Engineering

The Department is working within the Centre of Excellence on Mechatronics and Logistics for the development of three specific engineering areas:

1. *Careful scrutiny, testing and modeling of electrical units applicable for linear and rotating electromechanical actuators; improving suitable and accurate diagnosis and appropriate methods* are carried out by a research group which is represented by an impressive list of scientific papers (28) based on individual and mainly team research achievements, focusing modeling, testing and measurement of alternator, cranking motor (starter) for internal combustion engines, complex drive chain, test rig development for drives, internet at the service of electrical machinery, vibration measuring instrument development without contacts. Specific actuators development and ICT application in health diagnosis and in other electrical technology fields are also well-worth mentioning.

2. *Scrutiny of energy efficiency and quality of electrical distribution grid and scientific recommendations on the ways on how to eliminate various technical disturbances, mainly blackout* are dealt by another research team published 33 papers focused on energy saving technologies, application for greenhouse gas emission abatement, modular measuring instrument development for grid parameter identification, analysis of various power profiles with power fluctuation inclusive and controlled by voice frequency in the North-East region, information and communication systems development in some measuring instruments, data collection, virtual platforms, light emitting diodes (LEDs), testing for street illumination, power supply design for LED drives. Electrical power quality investigation by newly developed measuring instruments based on new synchronization theory is also carried out. All developed instruments and systems provide the chance to improve grid quality and protect the environment. *Improvement of respective higher engineering education post-2010* was in the center of research by Department academics, researchers and PhD students. This group runs EC Jean Monnet program, published 13 studies in the field of research on theory of higher engineering education like EU integration, connection between industry competitiveness and graduates output, new scientific aspect of continuing engineering education, Bologna process application in higher engineering education, development post-2010 underlining new challenges, new sustainable curriculum development, academia-industry link, brain circulation, PhD programs in the international sphere and publicizing University of Miskolc achievements.

REFERENCES

[1] A Knowledge-intensive future for Europe. Expert Group Report. European Research Area. European Commission, EUR 24165 EN, p.33. Brussels, Belgium, October 2009.

[2] research*eu. the magazine of the european research area. European Commission. Brussels, 2007-2010 issues.

[3] European Commission Report. A more research-intensive and integrated European Research Area. p.169. Brussels, 2008.

[4] Preparing Europe for a New Renaissance. A strategic view of the European Research Area. First report of the European Research Area. European Commission, EUR 23905 EN, p.28 Brussels, Belgium, 2009.

[5] Borri, C. and Maffioli, F.: Re-engineering engineering education in Europe. pp. 190. Firenze University Press, Firenze, 2007.

[6] Szentirmai, L. and Radács, L. (2011): New Requirement for European Academia-Industry Link – Sustainability and Competitiveness Improvement. International Conference on Engineering Education (ICEE 2011), Belfast, Northern Ireland, United Kingdom, 2011.

[7] Application for Excellence/Research University Title/Award (in Hungarian: Pályázat Kiválósági/Kutató Egyetemi címre) University of Miskolc, Hungary, p.60, 2009.

[8] Váradi, A. Sz., Patkó, Gy. and Szentirmai, L.: Higher Engineering Education by 2020 – The World Class Player on Future Economy's Stage. 40th SEFI Conference, Thessaloniki, Greece, September 2012.