Skills for future engineers: challenges for universities in Bulgaria

ELISSAVETA GOUROVA
Faculty of Mathematics and Informatics
Sofia University
125, Tzarigradsko shosse Blvd., bl. 2, Sofia
BULGARIA
elis@fmi.uni-sofia.bg http://www.fmi.uni-sofia.bg

YANKA TODOROVA
Faculty of Mathematics and Informatics
Sofia University
125, Tzarigradsko shosse Blvd., bl. 2, Sofia
BULGARIA
todorova.yana@gmail.com http://www.fmi.uni-sofia.bg

NIKOLAY GOUROV
Faculty of Automatics
Technical University - Sofia
8, Kliment Ohridski Blvd., bl. 2, Sofia
BULGARIA
nrg@tu-sofia.bg http://www.tu-sofia.bg

Abstract: - The paper considers the global *challenges for universities*, and the emerging models in higher education. It highlights the debates for e-skills in Europe and for skills needs of future engineers. A special focus is made on the educational environment in Bulgaria and the trends in last decade which have influenced the development of universities. The paper presents results of surveys carried out in two leading universities in Bulgaria – Sofia University and Technical University - Sofia, and the problems of skills and competences of their staff, organizational environment, as well as of collaboration with external stakeholders. On this base are considered some main steps towards improving the education framework in both universities, and putting it into a more strategic way.

Key-Words: - engineering skills and competences, education environment, university models, factors.

1 Introduction

More than a century ago the invention of the telephone facilitated the speed of knowledge transfer and communication among researchers world-wide, and created opportunities for fast changes in all scientific disciplines. Nowadays, the Information and communication technologies (ICT) accelerated enormously the technology development and innovation. Knowledge and information have become an important factor for competitiveness world-wide. Besides, the availability of highly-skilled workforce is essential for the productivity and growth of knowledge-intensive services and products [1]. The emergence of new scientific disciplines, requiring interdisciplinary skills and knowledge, has increased additionally the requirements for the skills and competences of the workforce. Presently, there are many evidences that engineers need not just technology knowledge, but also a number of non-technical skills in order to have better employment prospects and career advancement [2], [3], [4].

The needs for educational change have been discussed at several fora world-wide. The EU heads of state stressed at the Lisbon Summit in 2000 the need to foster the development of e-skills, entrepreneurial and innovation skills and creativity in Europe. During the last decade, the issue of skills was put on the agenda at different fora all around Europe. One action line was related to e-skills, and another – to entrepreneurial and innovation skills [5]. Generally, companies are seeking a combination of three types of skills of their future employees – technical, business and personal [6]. For engineering employees the skills set includes management of intellectual property and innovation, project management, business planning, etc. A serious need also exists for development of more forward-looking attitudes and leadership capacity [3].

Faced with the rapid technology changes, special focuses have deserved world-wide research and technology, innovation and education. In the triangle of knowledge, universities have a specific multidimensional role: creation and processing of knowledge, dissemination of knowledge during the teaching process, as well as permanent communication of scientific achievements [7]. Despite their traditional conservative nature, universities need to change and respond to the emerging economic and societal needs [8]. The changes go beyond the Bologna process, and require new focus on curricula development, teaching methods and environment, and grasping the opportunities of industry-academia collaboration, emergence of new scientific areas, and new learning methods and tools [2].

However, are Bulgarian learning providers ready to face the challenges of changing educational landscape and skills needs? What are present problems and actions taken? Which are the trends in industry-academia collaboration? These are some questions, which this paper highlights based on surveys undertaken recently at two large universities in Bulgaria – Sofia University (SU) [9], and Technical University – Sofia (TU) [10].

2 The changing educational environment

2.1 Global changes in higher education

The knowledge-based economy is characterized by increasing share of GDP of knowledge-intensive activities, and thus, higher demands for research, innovation and learning. Educational institutions have a special place in the society and provide services related to the transfer of knowledge to their customers – individuals, public and private organizations and the society in general. Their development is influenced by various factors linked to political, technological, economic, environmental, as well as social trends and changes.

In the knowledge society, lifelong learning becomes a permanent characteristic of present employees, whereas ICTs provide them a number of tools to enhance their knowledge and skills beyond traditional educational services [11]. ICTs are influencing large changes in universities, at organizational, methodological level, as well as providing greater power for research and lifelong learning [12]. New technologies provide many opportunities for universities to exchange knowledge and network with other partners locally or globally, and explore new collaboration ways. It is not surprising that virtual universities have emerged, distance courses, and a variety of e-Learning opportunities. As pointed out in [12], ICTs are influencing four scenarios for universities:

- Back to the basics' – The higher education institutions focus on the traditional, campus based students, in which learning takes place through face-to-face contacts and through direct interaction with instructors. Instructors and students are using word processors, email and WWW browsers, getting course information via WWW environments.
- The Global Campus' - Students study in a well-planned program and participate on-line in the program of a university, even if they don't physically ever come to that institution.
- Stretching-the-mould' - The students have no particular interest in being involved in a program or course offered at a distance, but would appreciate more flexibility in their local study setting. They might like to substitute some courses from the home institution by courses from another (including foreign) institution. The institution responds to the learner and it may cooperate with foreign partners in order to widen the choice for international on-line options within a common course management and ECTS.
- The New Economy' - The students wish to make their own decisions about what, when, how, where, and with whom they learn. The students will often be working professionals, and have a good idea of the types of courses or learning experiences that would be useful to their work setting.

New technologies and the emergence of Web 2.0 lead to take up of collective intelligence and collaboration – sharing of new content and networking among Internet users, which could essentially influence education and learning outcomes [13]. Subsequently, the appearance of University 2.0 model is considered, which integrates ICTs in its activities and emerges from the social computing phenomenon based on Web 2.0 [14].

It is well-known that many European and developed countries suffer demographic decline and the low birth-rate could influence educational institutions. A report of the World Economic Forum [15] considers that Europe is at risk due to the demographic shifts expected. The trend of longer life expectance and declining birth-rate will lead to ageing of EU population and low enrolments in universities of young people. At the same time, there is increasing demand by adults to gain new knowledge and enhance their competences beyond secondary education, which could balance the decline in traditional enrolment [16].

The emergence of new actors providing educational services to present employees – certification programmes, training courses, distance education, etc. increase the competition on the educational market. It is influenced also by the globalization: the emergence of virtual universities and a large number of joint educational programmes, as well as the students' mobility. On top of this, the financial crises enhances the trend for declining funding of higher education.

Subsequently, in [17] are considered four main factors with a strong influence on universities:

- Change in mission and participation at university – from 'elite' audience towards mass education.
- Greater autonomy for universities and entry of new private providers.
- Large differences among universities across the world, but changes in a more globalised and liberalised world.
- Impact of ICT bringing new avenues for teaching and research in higher education.

It is not surprising that different models of universities are described in research, differentiated according to their mission, teaching style, ICTs usage, etc. [12]:

- Research universities [18] offer a full range of baccalaureate programs, and are committed to graduate education through the doctorate, and give high priority to research.
- Entrepreneurial university [19] can only effectively become incubators of entrepreneurship and innovation if they alone practice entrepreneurship. They collaborate with other academic institutions, business and industry, much like a private enterprises. Organizational pathways of transformation are highlighted and consist of: a strengthened steering core; an extended developmental periphery; a diversified funding base; a stimulated academic heartland; and an entrepreneurial culture.
- Digital University [20] is characterized by efficient use of ICTs for improving substantially administration, research, teaching and further training at universities.
- Corporate university [21] is an educational entity that is a strategic tool designed to assist its parent organization in achieving its mission by conducting activities that cultivate both individual and organization knowledge and wisdom. Several corporate universities were established in the US by large companies in the 80s.
- Universities of Applied Sciences are designed with a focus on teaching professional skills. They represent a close relationship between higher education and the employment system. The students' up-to-date knowledge of the field enhances their preparation for professional life. Their practical orientation makes them very attractive for employers.
- Open university is a distance learning university and provides university education to those wishing to pursue higher education on a part-time and/or distance learning basis.
- Virtual university (virtual campus) is a metaphor for the electronic teaching, learning and research environment created using ICTs.

What their customers need, what are the requirements of their funding agents, and how their competitors change – all these issues face educational institutions with enormous challenges. For example, the EU outlines the following main challenges for them [22]:

- Increased demand for tertiary education
- Internalization of education and research
- Development of strong university-industry collaboration
- Proliferation of places where knowledge is produced
- Knowledge reorganization
- Emergence of new expectations.

Faced with the demographic and participation trends, organizational and content changes, decreasing funding and higher competition, now more than ever before state-owned universities have to become flexible and react rapidly to the dynamically changing environment in order to preserve their competitive advantage and survive on the global educational market [7].

2.2 The educational environment in Bulgaria

Bulgaria joined the EU in 2007 after a difficult transition period towards a market economy. The political and economic changes in the last two decades, and especially, the close-down of large enterprises negatively influenced higher education, and all universities have faced problems like ageing of staff and low interest by young people, lack of demand for research services by industry, and lack of investments in the material bases. This influenced the quality of education and reflected in low initiatives to change curricula for meeting industrial demands [23], [12].

Bulgarian universities suffered the transition period of the country, and at the same time, they had to change according to the new policy realms, and undergo restructuring following the requirements of the Bologna process and for joining the European Research Area (ERA). Opening up of the national system and creating synergies with other educational systems in Europe provided big challenges for Bulgaria, however, also a one-off chance for integration in the European knowledge system. The international recognition of the quality of teaching and research in higher education has been stressed as an important issue in the development of higher education. Therefore, several measures were taken in the Higher Education Act for [24]:

- Quality assurance of all university programmes by the National Evaluation and Accreditation Agency
- Innovation in teaching and learning methods
- Raising the scope of academic autonomy
- New funding schemes
- Improvement of evaluation procedures

The introduction of quality assurance according European standards in several universities has focused mainly on curriculum development standards and monitoring of the educational process [25], however, as pointed out in a Memorandum of the Union of Scientists in Bulgaria [26], there is a need to develop also scientific criteria for quality assurance, as well as success rate of students, employability criteria, and monitoring of future career path of graduates.

In Bulgaria, similarly to other New Member States (NMS) of the EU [27], the research system was characterized in the past by division of labour between very specialized higher education institutions (in charge of teaching) and the academic institutions specialized in research in different scientific areas. During the transition an emphasis was made for reintegration of research into the universities. Higher education institutes were affected by deep reforms related to greater autonomy of universities, adopting new democratic principles of governance, elimination of restrictions to academic freedom, etc. Following the Bologna process, a three degree tertiary education system was introduced in the country, including Bachelor (BSc), Masters (MSc) and post-graduate (PhD) studies. The establishment of a credit transfer system, compatible with the European credit transfer system (ECTS), was another challenge for Bulgarian universities, and paved the way for greater mobility of students and participation in the EU programmes for exchange of staff among universities [12], [24].

The administrative and structural changes in Bulgarian universities were accompanied by emergence of new academic curricula in tune with labour market trends and students' demands. Many new programmes have emerged that are professionally oriented and focus on the industrial needs for specific management (innovation management, quality management, information management) and multidisciplinary skills. However, the lack of strong university-industry collaboration in developing curricula and new programmes could be considered as a serious draw-back influencing the relevance of higher education to economic and societal needs.

The recent expansion of participation in higher education raises questions for the quality of teaching. A serious problem is related to the teaching staff, which has decreased significantly during the transitional period and is ageing rapidly. Besides, the lack of state funding for university research does not motivate sufficiently university professors to devote more time for research activities, which reflects the quality of teaching and the delivery of courses following recent advancement in the specific area. Low salaries, old-fashioned equipment, not sufficient recognition in the society, heavy and lengthy administrative procedures for career advancement are among the main barriers for new entrants in the teaching profession in Bulgaria [28]. The legislation for scientific degrees is old-fashioned and there is no political will for its change. This fact is creating enormous problems for the integration of Bulgaria into the ERA and the European Higher education area, as it raises barriers for researchers' career and mobility, and does not implement the principles of the European Charter for Researchers. The demographic change and the change of interest of young people towards economic, legal and societal areas in Bulgaria are considered at high level as a danger for future sustainability of technology education [7].

3 Towards interdisciplinary skills training

3.1 Skills sets needed for future engineers

Providing citizens and employees with a new set of skills and competences turned to be in the middle of all changes in public life and economy. ICT subjects were introduced in school curricula, a lot of initiatives were implemented for educating trainers, establishing computer labs in schools and connecting them to the global networks [6]. While the e-skills necessary for all European citizens are generally solved by educational systems, a lot of challenges remain for building the skills required by industry. Therefore, in the last few years the issue of e-skills was put on the agenda at different fora all around Europe – ICT Skills Monitoring Group, Career Space industry-led initiative, European e-Skills Forum, e-Skills and e-Learning expert groups at EC, ICT Task Force, etc. [9].

A large dialogue was launched between stakeholders for the e-skills and knowledge needs in Europe, which recently led to a new European e-Competence Framework (ECF) [29]. By developing it, the working group has accepted a definition for competence as 'a demonstrated ability to apply knowledge, skills and attitudes for achieving observable results'. Different ICT processes (Table 1) were considered each of them requiring specific competences in order to support the ICT knowledge areas (Table 2) covered by the framework [30].

Table 1 ICT business processes, Source [30]

Plan	Build	Run	Enable	Manage
Examples: Conceiving, Designing	Examples: Developing, Integrating, Testing	Examples: Controlling and exploiting operations, Maintaining, Supporting, Training, Documenting, Transitioning	Examples: Security, Quality management, Marketing and selling, Distributing/supplying, Procuring, Acquiring (incl. outsourcing), Disposing	Examples: Managing and operating, Defining strategies and applying, Risk management, Forecasting, Improving, Innovating

Table 2 ICT knowledge areas, Source: [30]

ICT Knowledge Areas						
Microelectronics, Components, Semiconductors, etc.	Computing Hardware	Industrial Control Systems	Communication equipments and services	Software Infrastructure	Business applications	System Integration

Subsequently, for each of the business processes was associated a level of the ECF, and were considered typical tasks, their complexity, autonomy and behavior, which were linked to the required knowledge, skills and competence [31]. The main objective was to set up a common reference framework which would serve as a translation device between different qualifications systems and their levels in higher or vocational education and training (Fig. 1).

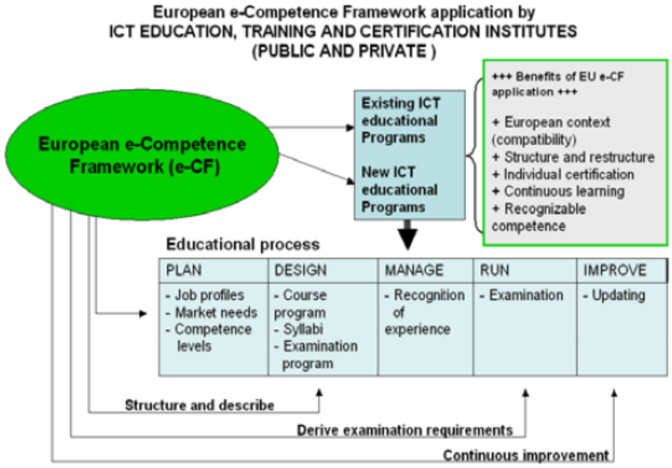

Fig. 1 Application of ECF in education, Source: [30]

Generally, e-skills could be considered as part of engineering skills, as the knowledge areas described in Table 2 belong to the engineering profession. However, engineers in power energy supply, machinery, metallurgy, chemistry, construction, etc. would need on top of e-skills also specific knowledge in their field.

For the skills' needs of future engineers several countries have considered also their national requirements [3]. It was recognised that engineering employees need not just basic knowledge of their profession (know-what), but to be able to apply theoretical knowledge in practical settings (know-how). At the in same time, present specialists practice their profession in a globalized environment, which requires ability to work in teams, collaborate sometimes in multicultural groups, which puts special requirements for their 'soft' skills. Thus, ability to communicate (with colleagues, providers, customers, etc.), keep certain ethical rules, be autonomous and proactive, adaptable to changes, etc. are a must for employees [32]. Engineers need also to understand better present-day trends in economy and society, and respect legal, social and environmental rules. The career advancement requires higher innovative culture, problem-solving skills and forward-looking attitudes. Last, but not least, leadership, business and entrepreneurship skills are more and more needed for employees nowadays [33], [34].

Summarising the debates on skills needs for future engineers and technology specialists, higher education institutions need to focus their curricula on delivering the following competences and knowledge:

- Technology specific – knowledge of specific area and its applications, as well as interrelated technology disciplines.
- General engineering knowledge – including mathematical and scientific background, material sciences, measurement, control and quality assurance, engineering system approach, analytical and engineering problems' solving skills, computer applications, knowledge of contemporary technology and economy trends, health and workplace safety, etc.
- Management skills – starting from leadership and visioning skills, goal setting skills, innovation and relationship management, entrepreneurship and risk taking abilities, change management, etc.
- Personal skills – interpersonal and team working skills, communication and presentation skills, professional, ethical, social and environmental responsibility, self-assessment and self-management, creativity and initiative-taking skills, flexibility for change and lifelong learning attitude.

Presentation skills are one of the basic skills needed by all employees, as this comprises all aspects of working life, starting from job interviews, dealing with every-day life issues, public relations, cultivating clients and solving problems, up to running a business or delivering speeches, chairing a meeting or even teaching [33].

Special emphasis should be made also on entrepreneurship skills, as in the fast changing environment nowadays it is important to be able to grasp emerging opportunities and turn ideas into success. Therefore, students need to be able first, to recognise opportunities, second, develop them and evaluate their possible practical implementation. For this is necessary not just technology knowledge, but also aversion to risk, creativity and vision, ability to anticipate and respond to social changes [34]. A recent study [35] points out that entrepreneurship is embedded in a social context, and implies an ability to recognize, exploit, and take risks in seizing entrepreneurial opportunities. Different schools emphasize different factors for entrepreneurial bahaviour, varying from effective leadership style, business capability, innovation and creativity up to personal characteristics and teamwork [35]. Entrepreneurial competency is considered also as a sum of the attributes for successful and sustainable entrepreneurship, including attitudes, values, beliefs, knowledge, skills, abilities, personality, wisdom, expertise (social, technical, managerial), mindset and behavioral tendencies [36].

3.2 Cases in Bulgarian universities

Many Bulgarian universities have followed the labour market needs and have introduced new courses providing added-value and interdisciplinary skills of their students. In order to highlight much better recent trends in Bulgaria, cases from two leading Bulgarian universities are presented below.

The Technical University – Sofia is the leading Bulgarian higher education institution in the field of engineering. There is hardly any industry, company, or plant in Bulgaria where TU graduates are not employed. In addition, TU has trained most of the academic staff working at other higher technical schools in Bulgaria [10]. It has responded to the changes in educational landscape in Bulgaria with introducing highly-demanded programmes in German and English in collaboration with EU partners.

For example, the English Language Faculty of Engineering (ELFE) was established in 1992 under a Tempus project initiated by staff of the Faculty of Automatics (FA). ELFE is a virtual TU faculty with BSc and MSc courses in English, based on a study programme which covers the content of the Industrial Engineering Specialty at the Brunel University, UK and the University College Dublin, Ireland. In addition to Industrial Engineering, in 2007 ELFE staff initiated two new MSc programmes: Business Computing and E-Management which provide additional opportunities to future engineers to combine technology with economic knowledge and skills.

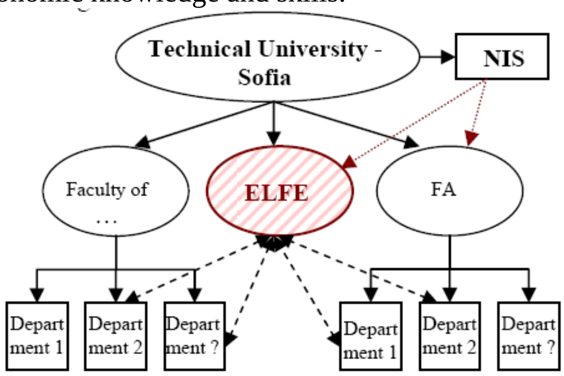

Fig. 2 ELFE position within TU – Sofia structure

Since its foundation ELFE is managed by FA staff and involves a large number of well-known professors from almost all TU departments (Fig. 2), many of whom have been trained under joint projects for academic exchange or research with other European universities. ELFE students have followed the lectures also of a number of invited guest professors coming from universities in UK, Ireland, Germany, the Netherlands, US, Japan, etc.

Different ELFE activities have contributed to the international integration and academic recognition of the courses and modules taught – the application of ECTS, and the bilateral agreements signed with several European Universities. ELFE has established good partnership with universities in the UK, Sweden, Spain, Portugal, Italy and Germany. ELFE students regularly compete in the students' and young researchers' conference for best project at the Technical University of Istanbul, participate in the Summer Academy, organised by DAAD in Ohrid, Macedonia or visit other universities within the Erasmus program for mobility.

As a second example, Sofia University is the first university in Bulgaria, established more than a century ago. It is also an important resource bank of researchers for the country. Its Faculty of Mathematics and Informatics (FMI) has a leading position among Bulgarian research organizations working in the field of ICT [9]. Aware of the global changes and the demands of knowledge society, FMI is trying to supply Bulgarian ICT industry with high-level experts equipped with new skills and competences. Therefore, on the bases of the Association for Computing Machinery/Institute of Electrical and Electronics Engineers (ACM/IEEE) Computing Curricula 2001 and the Career Space curricula guidelines, at the Faculty were developed and started new Bachelor programs on Computer Science, Software Engineering and Information Systems [12], [37]. In the design of the curricula were taken into account the Career Space core elements (Fig. 3) and provided a balance between them in the respective FMI programmes. The new BSc programmes found a high demand by the students and appreciation by industry.

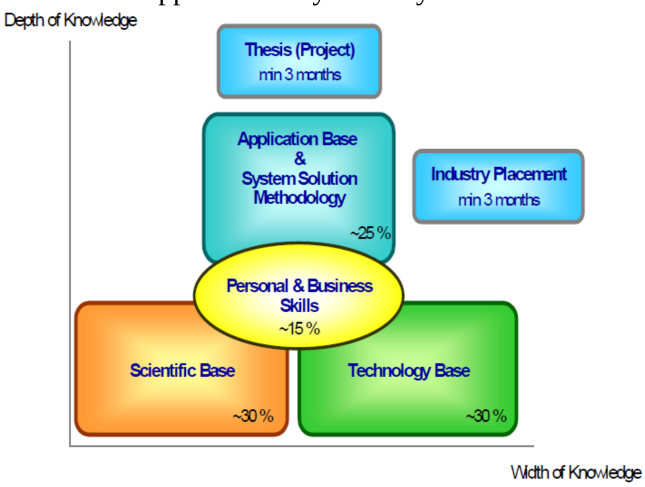

Fig. 3 Scope of competences, adapted from Career Space

In addition, FMI started successfully a large number of Master degree programs, such as Information systems, Mobile Technologies and Distributed Systems, Software Engineering, Information Security, eBusiness and eGovernance, Computational Science and Engineering, Artificial intelligence, Mechatronics and Robotics, Computer Graphics, Bioinformatics and Medical Informatics, etc. Most of the programs include compulsory or elective internship student placement [38].

The lack of focused training in management and entrepreneurship was identified as missing component in ICT experts training at FMI. Taking into account this fact and the expressed interest for interdisciplinary skills and management competences for ICT specialists, in 2007 was launched a new MSc program for Technological Entrepreneurship and Innovation in IT (TEIIT). The program offers a unique combination of business and global management topics focused on IT entrepreneurship. It aims to prepare next IT entrepreneurs in the region, delivering innovative and practice-based training. The program was inspired by University of California Berkley curriculum (Fig. 4), and was supported by Intel Europe [39].

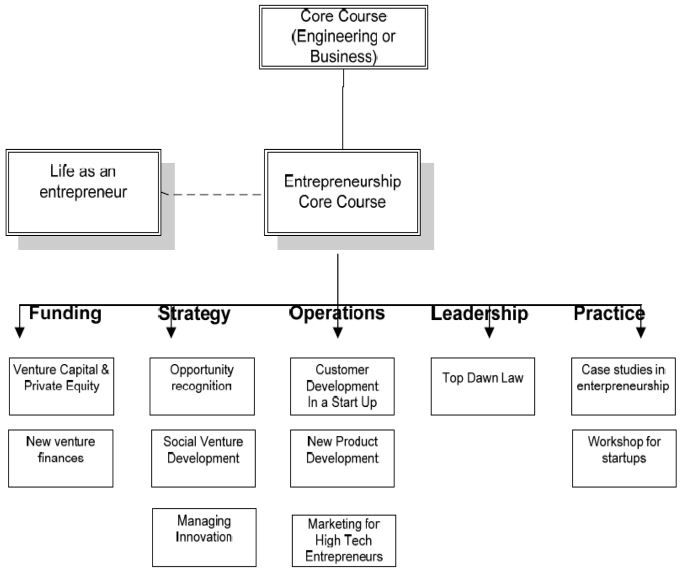

Fig. 4 The UC Berkley – Entrepreneur Curriculum

4 Readiness of Bulgarian universities to respond to present challenges

The general environment for higher education and the specific trends on Bulgarian education market raise the question if Bulgarian universities are ready to respond to contemporary challenges and what are

their needs in order to adapt rapidly. Two recent surveys carried out in May 2008 at FMI and in January 2009 in FA, try to put light into this issues.
The Faculty of Automatics was established in 1974. It is one of the biggest faculties of TU, and the leading centre for research and education in Control Engineering in Bulgaria. Its members are authors of 112 university course-books and 59 monographs. FA consists of 5 departments, which support their own well-equipped laboratories in automation, computing, electrical engineering theory, electrical drives, electronics, measurements, decision support systems, robotics, bioelectrical engineering, autonomous agents and artificial intelligence. The Faculty lecturers teach students from 6 basic faculties of TU, as well as from 3 Foreign Education Programme Divisions – the English Language Faculty of Engineering (ELFE), the French Faculty of Electrical Engineering and the Faculty of German Engineering Education and Industrial Management. FA has been attracting a large number of high-quality students, part from which are from Greece, Turkey, India, etc. The annual average number of papers in prestigious journals and conferences (IFAC, IMEKO, IEEE, IFIP, etc.) of FA amounts of about 120 .
The Faculty of Mathematics and Informatics is the successor of the former Physico-Mathematical Department founded in 1889. From 1986 it exists as a Faculty of Mathematics and Informatics at Sofia University. Currently, the number of full-time students at FMI is about 2 300 distributed in bachelor, master and doctoral degree programs in Informatics, Computer Science, Software Engineering, Information Systems, High School Teachers in Mathematics and Informatics, Mathematics and Applied Mathematics. The training is performed in 14 departments by full-time lecturers (about 70 Professors and Associate Professors and more than 80 Assistant Professors) and by guest-lecturers who are well-known scientists from Bulgaria and abroad. FMI and its students have at their disposal a library with about 80000 volumes which contains the oldest collection of mathematical literature at the Balkan states.
The surveys used the same methodology and made a SWOT (Strengths Weaknesses Opportunities Threats) analysis of the faculties. The main goal of the surveys was to collect some quantitative data provided by the researchers, but also to summarize the personal attitudes of the staff and their approach to research activities. The surveys focused on the following issues [9], [10]:

- Faculty staff experience, skills, and research interests and needs;
- The research priorities according to the staff – on European, on national, and on personal short-term and long-term levels;
- The personal assessment of the organization and work within Faculty;
- The evaluation of the overall national environment and attitudes toward researchers and research career in Bulgaria.

In the surveys participated 26 FA researchers and 22 FMI researchers, among them 42% over 45 years, and 36% younger than 35 years. The gender balance is in man's favour– 62% man replied to the questionnaire. Most of the respondents (51%) are in the beginning or at the middle of their research career taking Ass. Professor positions, whereas only 9% have a full Professor degree and 43% - Associate Professor degree. The profile of the respondents further shows that most of them are involved mainly in teaching, research activities and mainly from FMI in new technologies acquisition, whereas very strong experience in innovation and R&D, and cooperation with partners have respectively 25% and 21% of them.

4.1 Skills needs and research achievements

The surveys revile the strong technology competences of researchers and their knowledge of software products. It is interesting to note that the main skills needs of researchers are related to 'soft' skills, e.g. for team work (31% for FA and 30% for FMI), research management and teamwork (35% for FA and 34% for FMI), organizational and interpersonal communication and presentation skills (35%), and on a second place, general skills and competences, e.g. related to management of projects (35% for both faculties), quality (27%), planning (27%), etc. (Fig. 5 and Fig. 6).

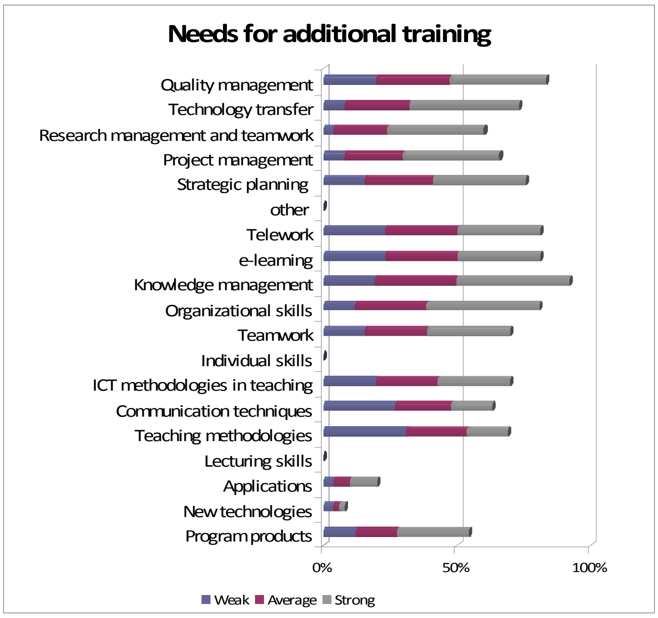

Fig. 5 Needs for additional training in FA

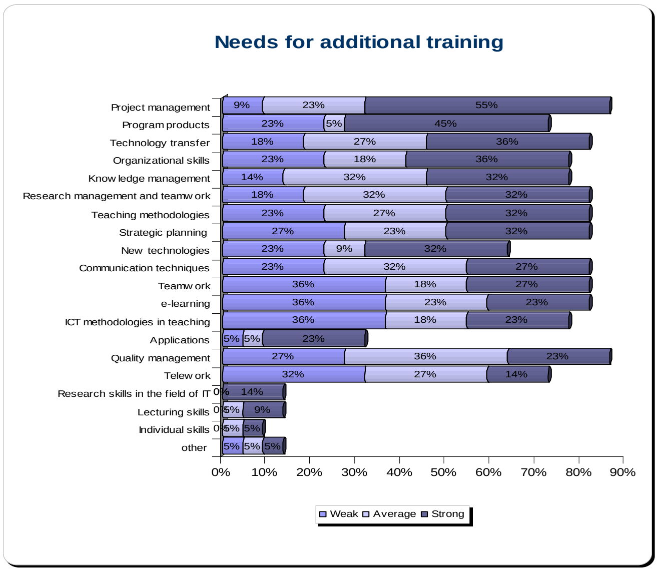

Fig. 6 Needs for additional training in FMI

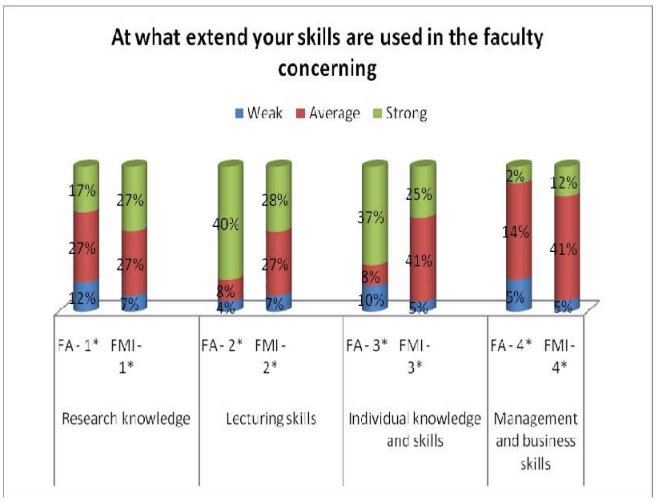

Fig. 7 Skills used in faculties

In addition, experience in work with end-users and in administrative tasks is lacking by 18% of the respondents. It is not surprising that the researchers from both universities consider that their lecturing skills and individual knowledge and skills are strongly utilized at their faculties, while management and business skills – at much moderated level (2% for FA, and 12% for FMI). As it seen from the graph (Fig. 7), researchers from FA evaluate that faculty utilizes mostly their lecturing skills (40%) and their individual knowledge and skills (37%). As for the FMI it is respectively 28% for their lecturing skills and 25% for individual knowledge and skills.

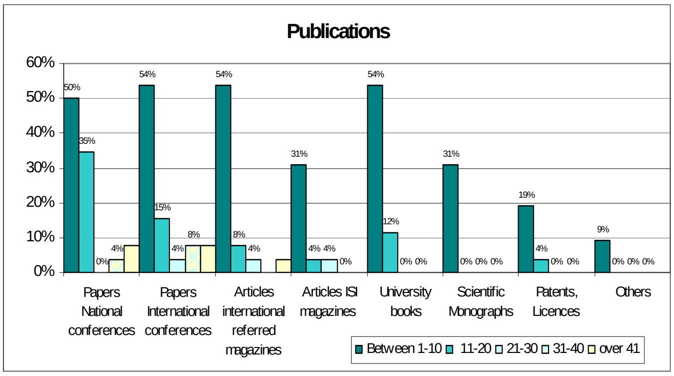

Fig. 8 Publications activity of FA researchers

As shown on Fig. 8, FA researchers have strong publication activity – almost 10% of them have higher than 40 papers at national and international conferences. As the dominant part of the respondents are in the beginning or in the middle of their career, the number of articles in referred and ISI magazines shows a good level of FA research results, as well as the availability of patents or licenses by 19% of the respondents.

The publications of FMI researchers are made mainly on conferences and international magazines (Fig. 9). For example, about 18% of FMI researchers have up to 30 publications, 14% - up to 20 publications and 59% - up to 10 publications on International conferences. About 59% of FMI researchers have up to 10 articles in International and ISI referred magazines. More than a half have published university books. FMI staff definitively lack experience in Patenting, which can be defined as one of the weaknesses for further knowledge transfer and links with the industry.

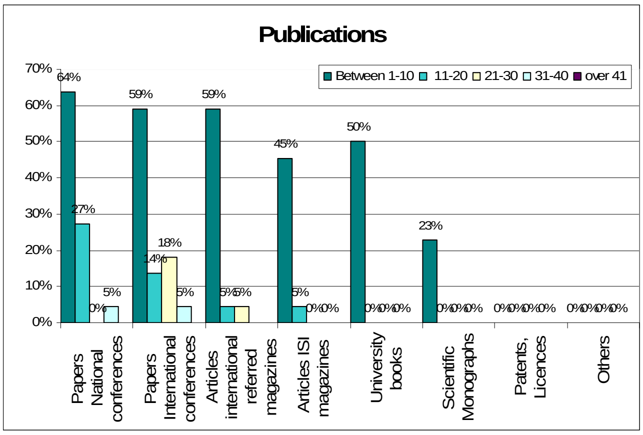

Fig. 9 Publications activity of FMI researchers

FA researchers outline as main short-term priority areas for their Faculty: robust control and up-to-date control algorithms, neuron networks, information systems, energy systems management, intelligent systems for measurement and control, biotechnology, Renewable energy sources, control design and implementation, etc. [10], while FMI researchers summarize as main short-term priority areas for their Faculty: knowledge management systems, digitalization of the scientific and culture heritage, intelligent systems, e-learning, e-content, e-government, e-work, ICT strategy, innovation and technology transfer, knowledge management, software and services; and web design, e-business application software, artificial intelligence [9].

Some differences appear also in the considerations of research needs for society and economy, based on the different background of the respondents. For example, FMI researchers consider a large ICT research infrastructure, software and services, ICT security, eLearning, intelligent content and semantics, enterprise interoperability, e-governance, e-health, computational modelling, gaming as important research areas, whereas FA researchers focus also on some wider issues, not linked to their own research, such as: quality control, renewable and alternative energy resources, high tech industry encouragement, higher research intensity in industry, energy and energy efficiency, environment, healthcare, communications, intelligent systems, safety, sustainable development [9], [10].

4.2 University environment

Most respondents consider that strategic planning at their faculty is at average level (Fig. 10 and Fig. 11), dominated by good formalized, monitored and controlled learning activities (35% for FA and 36% for FMI), however, formal mission and vision statements are not sufficiently well established (strong recognition of mission, vision, priorities, measurable objectives and activities is stated as 13% for FA and 0% for FMI), as well as the research and innovation planning. The faculty objectives are considered in line with national and European objectives by majority of the respondents (on one side, the faculty objectives are considered by 29% of the respondents from FA as strongly in line with national and European objectives, and by 31% as average in line, and on the other side, 5% as strongly in line and 32% as average in line). Only 12% of the respondents point out a lack of clear standards for efficiency measurement.

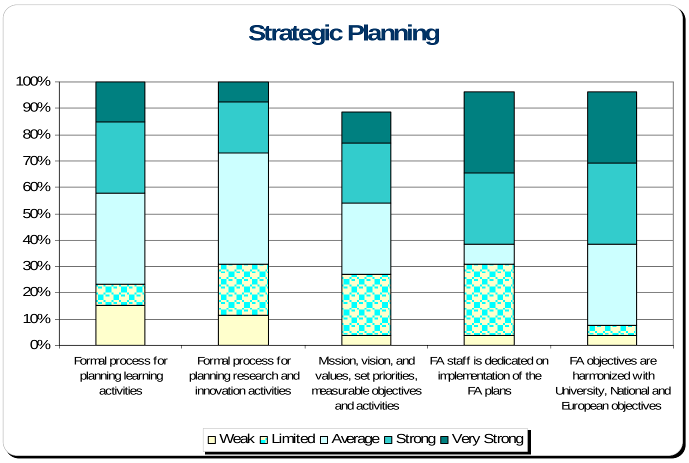

Fig. 10 Strategic planning at FA

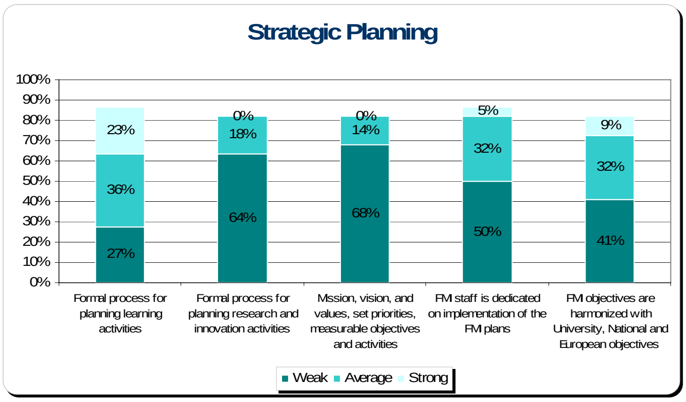

Fig. 11 Strategic planning at FMI

The assessment of FA infrastructure and resources (Fig. 12) points out that the Faculty possesses to a certain extend of a modern research and training labs, modern ICT technologies for lecturers. The provided access to actual research and training literature and access to periodic literature from recognized sources seems not to be vey strong point of FA, whereas there is obviously a need to employ enough researchers, lecturers and technical support staff.

As far as existing infrastructure and resources are concerned, FMI researchers point out some material problems, including lack of access to recognized literature sources and magazines, learning materials, as well as lack of enough researchers, lecturers and technical support staff and last, but not least, lack of modern research labs (Fig. 13).

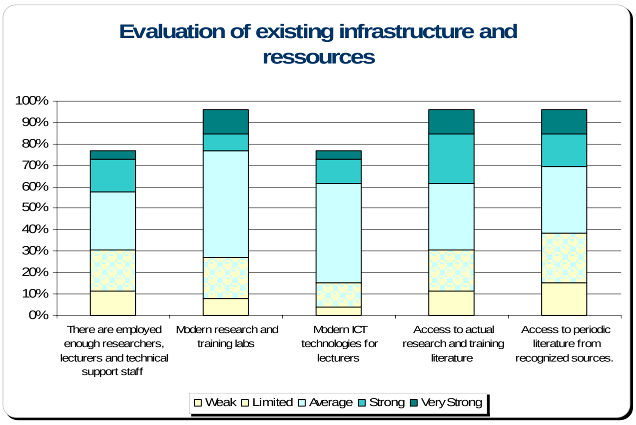

Fig. 12 Evaluation of existing resources at FA

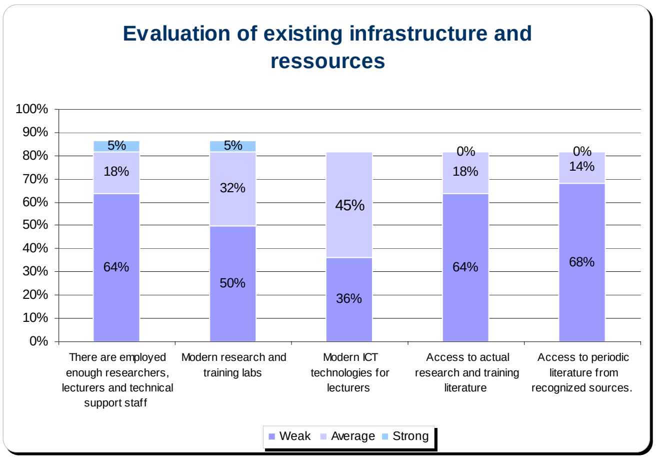

Fig. 13 Evaluation of existing resources at FMI

It is not surprising that the state policy and the general research environment seem to be the main threat for both universities' researchers. Most of them (89%) consider that the state does not support researchers, and that Bulgarian schools rarely encourage their students to enter a research career path (57%).

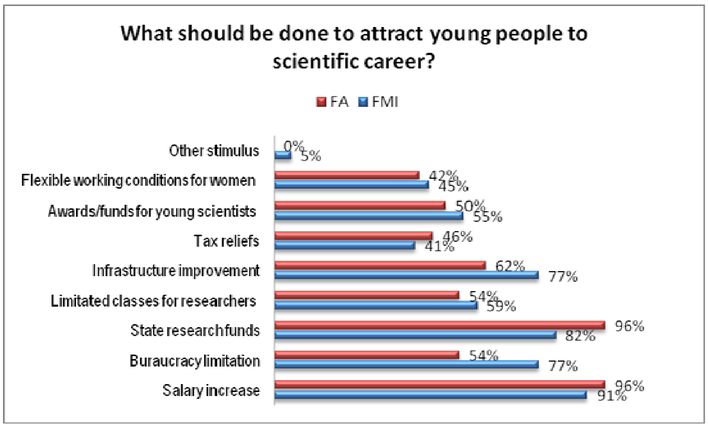

Fig. 14 Measures for attracting young people into research

Similar to other universities in Bulgaria, FA and FMI are not able to attract young researchers according to 61% of the respondents. Among the main incentives for attracting young people in research are considered salary increasing (94% - FA(96%) and FMI (91%)) and state research funding (89%), whereas bureaucracy limitation (65%) and infrastructure upgrade (69%) take a second place of importance (Fig. 14).

It is interesting to note that researchers from both universities consider the opportunities for work and career development as the most important conditions (77% for FA and 73% for FMI), whereas financial stimulus are at the second place of importance (31% for FA and 23% for FMI). In turn moral incentives have the least importance for researchers. (Fig. 15).

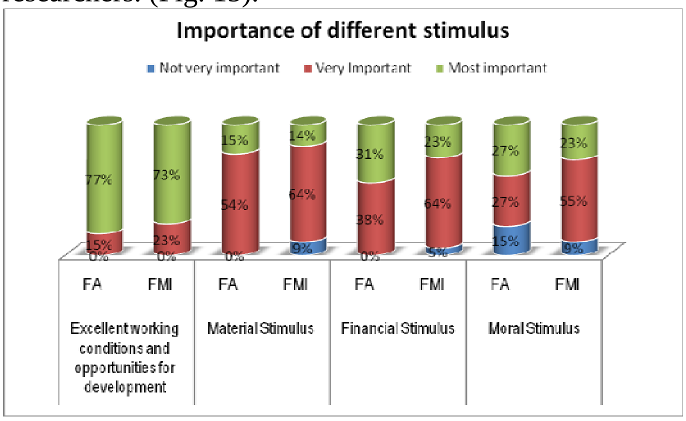

Fig. 15 Importance of different stimulus for researchers

Similar concerns regarding state policy and the general research environment in Bulgaria are expressed in survey carried out at national level within the FP7 project E*CARE of SU [28]. Among the main incentives for attracting young people in research are considered by most respondents higher salary, followed by the need to improve research infrastructure and decrease the bureaucracy for obtaining research degrees and positions. The results in Bulgaria do not differ much from the respondents from Greece, Czech Republic or Slovakia, where on average the research funding and stimulation for research is dominating in the opinion of researchers (85%), followed by salaries increase (72%), improvement of infrastructure (63%) and decrease of bureaucracy (31%) [40], [41]. Researchers consider the opportunities for interesting work and career development as the most important conditions for their career development (87%), followed by financial, material and moral stimulus [28].

It is interesting to note that most Bulgarian researchers responding to E*CARE survey, do not like to change their work to a position in the industry (67%), and only 28% show willingness to go to the private sector. In all participating countries of the survey the collaboration between academia and industry is not very well developed, whereas intensive joint research projects are pointed out by 10% of the respondents, 8% consulting to industry and 14% participation of industrial experts in research boards [42].

4.3 Industry-academia collaboration

The collaboration with stakeholders and acquiring regularly feedback from them seems to be much better established at FA according to the surveys' respondents (Fig. 16). In addition, higher percentage of FA researchers (27%) considers that the information gathered is utilised for improving the overall performance of their Faculty (for FMI the percentage is stated as 3%). This fact is to a certain extend due to the longer traditions in collaboration with stakeholders of the Technical University – Sofia. Among the achievements of FA researchers could be noted as well some patents, whereas FMI respondents did not report any patenting activities.

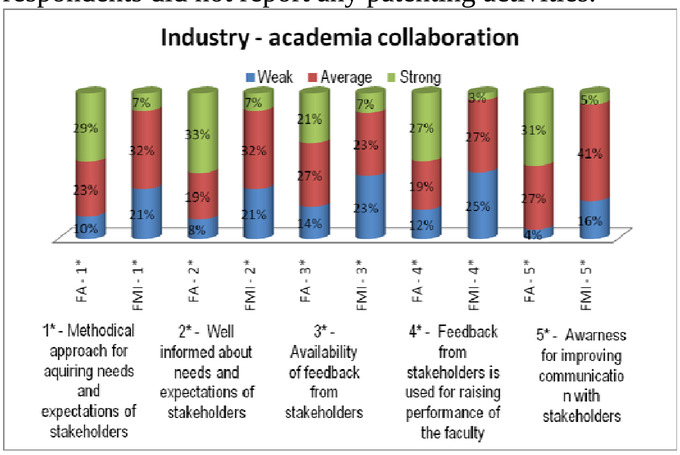

Fig. 16 Collaboration with stakeholders

Actually, these results do not differ very much for the general picture in Bulgaria. Industry-academia collaboration is reported for years as a weakness, and several measures have been taken to overcome it. For example, in the National Innovation Strategy is considered [9]:

- To stimulate R&D in industry and strengthen cooperation between R&D departments, universities and companies;
- To increase the financing of innovation through the creation of mechanisms for attracting private investments;
- To encourage companies to introduce new technologies and to improve their innovation activity;
- To encourage the establishment of clusters in traditional sectors;
- To support start-ups and well-functioning companies with the aim to increase their innovative potential
- To build up mechanisms for attracting foreign investments to scientific areas.

Similar to many EU countries, Bulgaria is facing the lack of efficient and stable research and industry collaboration, and integrity of the elements of the national innovation system [43]. The lack of a university structure to facilitate the knowledge and technology transfer is one of the emerging needs of most Bulgarian universities, in order to foster innovation and collaboration with industry. Therefore, the creation of Intellectual Products centres and the establishment of Technology Transfer Offices (TTO) in 2007 in many of the universities can be seen as an important step to enhance industry-academia linkages in Bulgaria and exploit much more the research results and knowledge created by universities [44].

5 Further challenges for Bulgarian universities

The paper outlined that TU and SU have achieved many successes during the last decades despite the overall economic changes and their impact on the environment for research and education in Bulgaria. This was driven by leaders who fully understand that the global race for knowledge, the acceleration of technology development and the emergence of a number of interdisciplinary scientific areas, further increase the challenges for research and industry organizations. At the same time, there are still a lot of challenges for the teaching staff and needs for changing of universities environment to motivate the staff and attract young researchers.

First, there is a need of changes in the national environment for higher education by setting clear priorities for education, decreasing administrative barriers, and linking labour market demands with universities' supply.

Second, changes are need also at universities – to equip researchers with the skills needed for the knowledge society, to provide them better career development and research opportunities, as well as to improve the technology environment and the access to scientific resources.

Last, but not least, there is a need for diversified funding at universities. Thus, collaboration with other stakeholders, both local and global, could be of benefit for streamlining educational efforts toward industry and society needs, as well as attracting funding for university activities in education and research.

In order to keep and extend further the positioning at national and European level, and the recognition for student excellence, there is still a long path to go. Therefore, some important challenges need to be integrated in the university strategies as proposed in the recent FMI strategy [38]:

1. Undertake continuous efforts to increase the quality of education, training, research and information services to gain program competitiveness, ensure high levels of achievement and knowledge.
2. Ensure that education and research services are relevant to the needs of Bulgarian citizens, labour force, industry, local and state government.
3. Provide individuals of all ages access to education, training and information services in order to develop their competences and to become globally competitive workers, responsible citizens, capable for lifelong learning.
4. Ensure efficient operation and management of the education and research system, and investments in ICT focused on student learning, in order to reach greatest benefit from education and research resources.

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