Building a Research University Ecosystem: the Case of Software Engineering Education at Sofia University

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ABSTRACT

This paper analyses the specifics and the tendencies in building of the knowledge society and the role of the universities in this process. Some European policies and programs dedicated to the new role of the universities in realizing the Lisbon Strategy are analysed as well. It is emphasized on the importance of integration of the 'knowledge triangle' (education, research and innovation) into a research university and on the urgent need to re-design the university activities according the new requirements. This paper describes some real experiences, emerging models and lessons learnt based on the case of Software Engineering education and research being held at Sofia University.

Keywords

Knowledge society, universities in knowledge society, research university ecosystem, advanced education technologies, software engineering education.

1. INTRODUCTION

Sofia University "St. Kliment Ohridski" is the first school of higher education in Bulgaria. Today it is the largest and most prestigious educational and scientific centre in the country – with over 35,000 students studying in 76 Bachelor's and over 200 Master's degree programs. Since its establishment the university has always played a very important role for the development of the country. The university experiences a lot of challenges related to the overall transformation of the economic and social system in the country, the changing models of education, the new role of the universities in the knowledge-based society and the great demand for ICT specialists. Among the main challenges of the university is to become a national and regional high-technology and innovation centre, an entrepreneurial university that understands the commercial value of knowledge [13] and drives the country towards Knowledge Economy through building a sustainable university-industry-government partnership.

This paper analyses the specifics and the tendencies in building of the knowledge society and the role of the universities in this process. Some European policies and programs dedicated to the new role of the universities in realizing the Lisbon Strategy are analysed as well. It is emphasized on the importance of integration of the 'knowledge triangle' (education, research and innovation) into a research university and on the urgent need to re-design the university activities according the new requirements. This paper describes some real experiences, emerging models and lessons learnt based on the case of Software Engineering education and research being held at Sofia University.

The paper is organized as follows: Section 1 is Introduction and gives the basic information about Sofia University "St. Kliment Ohridski". Section 2 presents some European policies, programs and initiatives dedicated to the new role of the universities in the knowledge society. Section 3 focuses on Sofia University specifics in the light of economic, demographic and financial trends. Section 4 discusses the concept of building research university ecosystem. Section 5 presents the educational model used in Sofia University. Section 6 describes Software Engineering education in FMI for BSc and MSc levels with focus on Master one and main research topics. Section 7 concludes the paper with open issues and perspectives in Sofia University.

2. TOWARDS A KNOWLEDGE SOCIETY

2.1 From Industrial society through Information society to Knowledge society

Information Society is the successor to industrial society. The main characteristic of the IS is the dominant role of the Information and Communication Technology (ICT). The recent fast developments of ICT and its deep penetration into the society caused a dramatic change in the way people live, learn and work and this process is accompanied by social, industrial, and organisational reconstructions and innovations. The economist Fritz Machlup is considered as the pioneer who developed the concept of the information society and also discovered so called information economics [29]. Marchup considers university, being the center of knowledge production and teaching, as a "knowledge factory", equated to an industry [30]. Clark Kerr, former president of the University of California, Berkeley, cited Machlup's notion of the "*knowledge industry*" in his influential book "*The Uses of the University*" [28]. Kerr laid out his views that **a large modern university had to operate as a part of society, no longer as an ivory tower apart from it**.

Peter Drucker, in his book "*The Age of Discontinuity*", wrote a section on Knowledge Society referring to Machlup's findings [16]. Drucker predicted that, by the late 1970s, the knowledge sector would account for one half of the GNP, and this became true. Since then the terms information society and knowledge society has been matter of research and analysis for many researchers, politicians, technologists, educators and other stakeholders in the process of global change.

Knowledge has been at the heart of economic growth and the gradual rise in levels of social well-being since time immemorial

[15]. Knowledge economy is based on the activities of groups of people who produce and exchange (co-produce) new knowledge on a mass scale using information and communication technologies. The authors analyse the start of the digital era as a revolution in knowledge instruments, and as being of great importance since it influences the technologies used to produce and distribute information and knowledge.

Some analysts believe that information society has already come to an end and that the next stage in human evolution is a knowledge-based society, in which specialised institutions will no longer be happy simply to provide information but will also "plant" knowledge, through the direct involvement of information-science specialists (now known as "knowledge workers") in the knowledge process [8]. Since the beginning of the 20th century we have seen a new characteristic of economic growth in the form of greater "intangible" capital as compared to "tangible" capital [1]. The economies of developed countries are increasingly based on knowledge and information. The problem is that access to knowledge-based economies is still very restricted and there are big disparities between different countries and different social strata.

Knowledge was recognised by the Organization for Economic Cooperation and Development (OECD) as the driver of productivity and economic growth, leading to a new focus on the role of information, technology and learning in economic performance. The term "knowledge-based economy" stems from this fuller recognition of the place of knowledge and technology in modern economies.

2.2 World Bank Programme

The World Bank started the ambitious Knowledge for Development (K4D) Programme [40]. They point out that the increased importance of knowledge provides great potential for countries to strengthen their economic and social development by providing more efficient ways of producing goods and services and delivering them more effectively and at lower costs to a greater number of people. The knowledge revolution also raises the danger of a growing 'knowledge divide' (rather than just a 'digital divide') between advanced countries, who are generating most of this knowledge, and developing countries, many of which are failing to tap the vast and growing stock of knowledge because of their limited awareness, poor economic incentive regimes, and weak institutions. The Knowledge for Development Programme is based on the assumption that in order to capitalize on the knowledge revolution to improve their competitiveness and welfare, developing countries need to build on their strengths and carefully plan appropriate investments in human capital, effective institutions, relevant technologies, and innovative and competitive enterprises. The opportunities for rapid progress are well illustrated by countries like Finland, Korea, Ireland, Chile, etc. Finland, for instance, is a country that has successfully transformed itself into a knowledge economy in a short time [14]. The Finnish experience of the 1990s represents one of the few examples of how knowledge can become the driving force of economic growth and transformation. During that decade, the country became the most ICT specialized economy in the world and thus completed its move from the resource-driven to knowledge- and innovation-driven development. Four times to date at the beginning of the twenty-first century, the country has been ranked as number one in the World Economic Forum's (WEF) competitiveness index, and as one of the most developed IT economies. It was ranked top in the OECD's Program for International Student Assessment (PISA) studies of learning skills and educational attainment, and also achieved the highest Knowledge Economy Index in the World Bank comparisons [41]. The various elements pertinent to a knowledge economy—economic incentives, education, innovation, and IT infrastructure—also seem to be well balanced in Finland. As late as the late 1970s, Finland ranked at the lower end of the OECD countries in R&D intensity. Today, Finland's investment in R&D accounts for approximately 3.5 percent of GDP, which is the second highest in OECD and the third highest in the world, just after Sweden and Israel. **Education is considered as the key element of a knowledge-based, innovation-driven economy**. It affects both the supply of and demand for innovation. Human capital and skilled labor complement technological advances. Finland's innovation system successfully converted R&D and educational capacity into industrial strengths in close coordination between the public and private sectors.

2.3 European initiatives

2.3.1 Lisbon strategy

The Lisbon strategy and its objective to make Europe "*the most competitive and dynamic knowledge-based economy in the world*" led to important policy initiatives [18]. One of them aimed to refocus the European and national budgets on research and innovation, as stated by the Barcelona European Council and reach a level of 3% of GDP [19]. The Kok's Report [20] re-confirmed that Europe's future economic development would depend on its ability to create and grow high value, innovative and research-based sectors capable of competing with the best in the world. Among the main measures for achieving the Lisbon goals, Kok's report emphsises that Europe needs to build a "*creative interaction between universities, scientists and researchers on the one hand and industry and commerce on the other, which drives technology transfer and innovation, is necessarily rooted in the close physical location of universities and companies*". In addition, increased efforts should be mobilised at national and EU level by all concerned stakeholders to promote technological initiatives based on Europe-wide public–private partnerships.

EC very clearly recognized the role of the universities in building Europe of Knowledge [22]. All European universities are facing very serious challenges, such as:

- **Increased demand for higher education**. Despite of the low birth rate in Europe (and particularly – in Bulgaria) increased demand for higher education is observed and it is expected to continue in the next years.
- **The internationalisation of education and research**. European universities are attracting fewer students and in particular fewer researchers from other countries than their American counterparts.
- **To develop effective and close cooperation between universities and industry**. Cooperation between universities and industry needs to be intensified by gearing it more effectively towards innovation, new business start-ups and, more generally, the transfer and dissemination of knowledge.

- **The proliferation of places where knowledge is produced**. The increasing tendency of the business sector to subcontract research activities to the best universities mean that universities have to operate in an increasingly competitive environment.
- **The reorganisation of knowledge**. The universities should urgently adapt to the interdisciplinary character of most advanced research and development areas The activities of the universities tend to remain organised within the traditional disciplinary framework.
- **The emergence of new expectations**. Universities must cater for new needs in education and training which stem from the knowledge-based economy and society. These include an increasing need for scientific and technical education, horizontal skills, and opportunities for lifelong learning, which require greater permeability between the components and the levels of the education and training systems.

The EC aims at **increasing universities' excellence in research and teaching.** The European universities have to identify the areas in which different universities have attained some essential for Europe excellence and to concentrate funding on them to support academic research. The commission supports not only intra-European academic mobility, but also mobility between universities and industry, thus opening up new career opportunities for young researchers. The EC reports also that the number of young technological ("spin-off") companies created by universities has been on the rise in Europe. Their average density nevertheless is far smaller than it is around the American campuses. A major obstacle to better application of university research results is the way intellectual property issues are handled in Europe. In addition, European universities do not have well-developed structures for managing research results.

Another important measure is to **open up universities to the outside world and increasing their international attractiveness** and to prepare them to a broader international competition, especially with the American universities attract the best talent from all over the world. It is reported that the European universities host almost as many foreign students as American universities, in proportion they attract fewer top-level students and a smaller proportion of researchers. This means that the learning and research environment offered by the European universities is less attractive. The regions of the EU are supposed to play a very important role through the development of technology centres, science parks, and other cooperation structures between the business sector and the universities, and thus - to catalyze development of university regional development strategies and stimulating regional networking of universities.

The EC considers the universities as motors of the new, knowledge-based paradigm but clearly states that "*they are not in a position to deliver their full potential contribution to the re-launched Lisbon Strategy*" [21]. The main conclusion is that "*Europe must strengthen the three poles of its knowledge triangle: education, research and innovation. Universities are essential in all three. Investing more and better in the modernisation and quality of universities is a direct investment in the future of Europe and Europeans.*"

The European University Association defines some leading principles the European universities should follow in order to meet the challenges of the Europe of Knowledge [27]:

- universities provide a *unique space for basic research*;
- universities play a *crucial role in the training of researchers* thus ensuring the continuity of the "research pipeline";
- universities are research institutions *based upon the integral link between teaching and research*;
- universities pursue excellence in disciplinary research, and provide environments that enable the *cross-fertilisation of ideas across disciplines*;
- universities are knowledge centres that *create, safeguard and transmit knowledge vital for social and economic welfare*, locally, regionally and globally;
- universities are engaged in knowledge transfer as *full partners in the innovative process;*
- universities' willingness to *focus and concentrate their efforts through enhanced cooperation* and networking among themselves and with business, industry and other partners.

2.3.2 The Seventh Framework Programme

The **Seventh Framework Programme (FP7)** [23] tries to integrate all EU research-related initiatives in order build the '**knowledge triangle**' - **research, education** and **innovation** - is a core factor in European efforts to meet the ambitious Lisbon goals [25]. The FP7 tries to establish horizontal links with the new **Competitiveness and Innovation Framework Programme (CIP)**, Education and Training programmes, and Structural and Cohesion Funds for regional convergence and competitiveness. It is also a key pillar for the **European Research Area (ERA)**. **European Technology Platforms** (ETPs) [26] help industrial and academic research communities in specific technology fields to co-ordinate their research and tailor it to a common "*strategic research agenda*" (SRA), which sets out research & development (R&D) goals, time frames and action plans for technological advances that are relevant to industry and society [EC, 2006b]. SRA's aim is to mobilise a critical mass of national and European public and private resources. ETPs help industry and academia to better structure and co-ordinate their research in order to build links between the various elements of the innovation process.

2.3.3 The European Institute for Technology

The **European Institute for Technology** (EIT) is considered as an important step to fill the existing gap between higher education, research and innovation, together with other actions that enhance networking and synergies between excellent research and innovation communities in Europe [24]. The commission admits that Europe is good at inventing, but falls short in exploiting the results of its research work. The main reasons for that are:

- **Lack of critical mass:** The EU's higher education and research systems are too fragmented, leading to dispersed innovation efforts.
- **Not enough top-class excellence:** There are too few internationally renowned, excellent EU universities.

- **Low business involvement:** Low level of involvement of business in education and research.
- **Education and research structures** tend to stifle entrepreneurial initiative and rapid response to social and economic needs.
- **Brain-drain:** Working environments fail to attract or keep the best talents in Europe.
- **Lack of funding:** Insuffi cient private funding for education and R&D.

The EIT is considered as one part of an integrated strategy to mobilise education, research and innovation towards the Lisbon goals.

3. THE CASE OF SOFIA UNIVERSITY

Like all other Central and East European Countries (CEECs) Bulgaria is experiencing a dramatic change in all areas of its society. There is a lack of enough public support and understanding of the political and economic changes in Bulgaria. In addition, there is an urgent need to transform the existing companies to be ready for the knowledge economy and, at the same time, create favorable conditions for emerging private enterprises. This requires better knowledge in ICT, economics, business, company and knowledge management. Sofia University, as the national leader in higher education, plays a crucial role in this process by providing better e-skills oriented education and training, targeting the needs of the industry.

A growing demand for university level education is observed in Bulgaria – there is increasing number of candidate-students in conditions of a constant annual enrolment. Changes in the labor market and in the demand for new types of qualifications and a new graduate profile, as well as for demand for lifelong learning/continuing education are the reasons for increasing the number of part-time students and older students. A major threat to the technological development of the country lies in the emigration of high skilled professionals. During the last twelve years the Bulgarian population has decreased by nearly one million people. The majority of those who emigrated were well educated specialists. This fact causes great concern that it would be increasingly difficult for the Bulgarian system of education to, at least partially, make up for the high skilled migration with a new generation of high technology experts. In fulfilling this task Sofia University has a national responsibility.

Financial downturn seems to be one of the most important factors that affect the university development. There is a clear tendency of shrinking governmental funding for higher education, e.g. from 4.2% of GDP in 1991 to 2.2% of GDP in 1998. There is an almost total withdrawal of the government from scientific research. For instance, the R&D sector of Sofia University reported that:

- the income of the university for R&D from Bulgarian enterprises has declined 15-20 times since 1989;
- the income from university contracts with the Ministry of Education & Science has declined 500—700 times for the same period.

As a result, Sofia University, similarly to the other Bulgarian universities, is gradually loosing its capacity due to lack of enough funding and teachers. This tendency must end very soon.

Despite the negative tendencies Bulgaria is a rich reservoir of ICT specialists and the country is very popular as outsourcing destinations for software development and ICT services, as well as for establishment subsidiaries of large foreign ICT companies. The Bulgarian Competitiveness Initiative and the National Competitiveness Conference, 18-19 April, 2001, have sent a clear message: '*the stronger the university-industry-government cooperation is, the more competitive is the national economy*' [10]. According to the Overall Competitive Ranking presented at the Davos Forum, Bulgaria is ranked behind the first sixty countries. Both universities and industry in Bulgaria experience severe problems and they could hardly build a strong cooperation in a short period of time.

However some recent studies suggest that individual entrepreneurship has driven the take-up of many economic activities in Bulgaria. The emergence of a large number of small and medium size enterprises (SMEs) in the ICT sector, in particular, is largely attributed to individual entrepreneurs who have been able to start business from scratch and find market niches for growth. A lot of examples of successful ICT related businesses developed in an environment of uncertainties and risks, unattractive to foreign investors, could be observed in Bulgaria, and in other CEECs. Individual knowledge and skills, as well as entrepreneurship and leadership, have been important factors for the success of these companies.

Being fully aware of all of the above, Sofia University is taking measures to become more entrepreneurial and better recognize the economic value of knowledge. The academic staff should exhibit some of the characteristics of practicing entrepreneurs: they acquire contract research and contract teaching and engage in technology transfer projects. The university also tries to find a way to let its students, during the course of university studies, achieve the knowledge and skills needed to become individual entrepreneur. Because of its size, capital location, institutional prestige and available research resources Sofia University is able to achieve a substantial influence on the process of cooperation between universities, industry and administration. The question is: How could a large and 'classical university' becomes more entrepreneurial?

In conditions of an increasing competition with other universities in the country and abroad Sofia University seems to gradually loose some of its competitive advantages. The new private universities, such as New Bulgarian University, American University in Bulgaria and Bourgas Free University, are much more dynamic and entrepreneurial. The emerging e-Learning global education market is another strong driving force for becoming entrepreneurial. City University, USA opened a Distance Learning Center in Bulgaria a few years ago and later on it has evolved into a City University - Bulgaria branch. There are many Bulgarian higher education institutions - universities and colleagues that also provide ICT education and training. Several Greek universities and subsidiaries of Western universities are attracting the same target group as Sofia University does. For instance, City College affiliated to Sheffield University. There already appeared several accredited virtual universities, such as Jones International University and Cardean University - a 'joint venture' of Columbia Business School, Stanford University, University of Chicago Graduate School of Business, Carnegie Mellon University, and London School of Economics and Political Science. Sofia University should gear its organizational structure and management in order to become more competitive and adaptive to the local and international educational market. The university management feels the need for transformation and changes in the organizational structure and university behavior in order to make it more competitive and adequate to the economic and social situation in the country. Strengthening the role of **Sofia University as a research university** is among the main measures to be implemented along with improving the quality of education and training.

4. BUILDING A RESEARCH UNIVERSITY ECOSYSTEM

While the European Institute of Technology tries to integrate education, research and innovation at a MSc and PhD level, many of the American research universities target the BSc level as well [9]. The new model of such universities is to make the baccalaureate experience an inseparable part of an integrated whole. Universities need to take advantage of the immense resources of their graduate and research programs to strengthen the quality of undergraduate education. Some research faculties might find new stimulation and new creativity in contact with bright, imaginative, and eager baccalaureate students, and graduate students would benefit from integrating their research and teaching experiences. In this respect the research universities are very different from small colleges, and they can offer a learning environment which is not typical for the small colleges and non-research universities. The baccalaureate student who studies in such environment develops his or her own research capabilities. The research universities could be both student-centered and research-centered through a *"synergistic system in which faculty and students are learners and researchers, whose interactions make for a healthy and flourishing intellectual atmosphere"*.

Since the research universities commit to create new knowledge, they consider research capability as a primary qualification for appointment and promotion, and they are very proud on having world-class scholars among their staff. The America's research universities typically have an international orientation - they attract students, particularly at the graduate level, from many parts of the world, thereby adding valued dimensions of diversity to the community. The international graduate students often become teaching assistants, so their presence becomes a part of undergraduate experience. And many research universities offer an array of interdisciplinary programs seldom available in smaller institutions. The graduates of these programs make the names of the American research universities recognized and respected throughout the world.

The concept of integrated education at a research university requires restructuring both the pedagogical and the management aspects of the university. The Boyer's Commission defines the main goals of a research university, namely:

- Make the research-based learning the standard. The main principle is that learning is based on discovery guided by mentoring rather than on the transmission of information.
- Construct an inquiry-based freshman year. The first year of a university experience needs to provide new stimulation for intellectual growth and a firm grounding in inquiry-based learning and communication of information and ideas.
- Build on the freshman foundation. The freshman experience must be consolidated by extending its principles into the following years. Inquiry-based learning, collaborative experience, writing and speaking expectations need to characterize the whole of a research university education. Those students who enter the research university later than the freshman year need to be integrated smoothly into this special atmosphere.
- Remove the barriers for interdisciplinary education. Research universities must remove barriers to and create mechanisms for much more interdisciplinary undergraduate education.
- Link communication skills and course work. Undergraduate education must enable students to acquire strong communication skills, and thereby create graduates who are proficient in both written and oral communication.
- Use information technology creatively. Because research universities create technological innovations, their students should have the best opportunities to learn state-of-the-art practices — and learn to ask questions that stretch the uses of the technology.
- Culminate with a capstone experience. The final semester(s) should focus on a major project and utilize to the fullest the research and communication skills learned in the previous semesters.
- Educate graduate students as apprentice teachers. Research universities must redesign graduate education to prepare students for teaching undergraduate students as well as for other professional roles.
- Change faculty reward system. Research universities must commit themselves to the highest standards in teaching as well as research and create faculty reward structures that validate that commitment.
- Cultivate a sense of community. Research universities should foster a community of learners. Large universities must find ways to create a sense of place and to help students develop small communities within the larger whole.

Some European universities are also involved in designing new models for higher education in computing, such as the Active Learning in Computing (ALiC) initiative that aims to facilitate a shift towards far higher levels of active student engagement where knowledge is obtained by sharing, problem-solving and creating, rather than by passive listening [6]. The Techno-Café is proposed as an alternative of the typical university computer lab that provides flexible working environment that that allows a variety of learning activities. One of the main goals of ALiC is to demonstrate how to better integrate research and teaching activities by following the recommendations of Boyer's Commission Report and the Roberts' Report [33]. The Roberts' Report follows the development of science and engineering skills through school, further and higher education and draws some key recommendations in each area. The report identifies an existing gap in the supply of science and engineering skills in the UK and the difficulties employers face in recruiting highly skilled scientists and engineers since science and engineering graduates' and postgraduates' education does not lead them to develop the transferable skills and knowledge required by R&D employers. Many of the Roberts' Report recommendations resemble the ones of the Boyer's Commission.

5. USING ADVANCED INFORMATION AND EDUCATIONAL TECHNOLOGIES

Sofia University applies advanced information and educational technologies in higher education for more than 12 years now [34; 35; 37; 38]. Some basic characteristics of the targeted educational model are [34]:

- *Cooperative learning*, as an alternative of the *competitive learning* [31], is widely integrated and implemented in a highly interactive (virtual) learning environment comprising computer support cooperative learning systems.
- The *working on a project* school activity is accepted as an alternative of the traditional classes and realized according to the *project pedagogy* [31] principles, which is gradually shifted from the university settings to a school level now. Networked multimedia communication enables project teams working together independently of time and space.
- The teachers are given *higher degree of freedom* as the Internet allows them to work together across their classrooms and freely share ideas and experience. They facilitate students' inquiry, manage their learning process, and help them navigate in a shared global information space. The curriculum and the teaching and learning processes are highly individualized. Different pathways and support for learning are offered to students who can progress with a different speed. The school is open towards the world. The problems the students solve are formulated either by themselves or by the teacher and come from their everyday life. The students and the teacher cooperatively solve these problems.
- The design principles of the learning environment are based mostly on asynchronous space and time and interactive learning environments combining virtual and physical spaces. By complementing face-to-face interactions and digital communication, the physical constraints obstructing one-to-one consultation between a teacher and a student, as well one-to-many and many-to-many type of discussions, are significantly lowered, and all sorts of new pedagogical groupings may become both feasible and effective. All students have their own responsive ICT-based learning environment allowing communication with her peers, teachers, virtual friends, network servers, digital artifacts, etc. The virtual reconstruction of university spaces makes possible physically distinct spaces to be joined into virtual auditoriums, workshop rooms, reading rooms, cafes, libraries, where students from different locations can interact as if they were together face-to-face. The space, time, equipment, and all teaching materials and information resources could be used in an extremely flexible way. The system of forming classes by age might be quitted soon and students in different age might work and study in small groups.
- The main principle in the *learner centered pedagogy* is that the learners do not receive ready-made knowledge but rather they discover and construct their knowledge, which does not mean to reinvent it though. The students get opportunities to obtain knowledge both in the school settings and outside school system. The students obtain new knowledge while solving real problems and transfer their knowledge to other students. They learn autonomously taking the responsibility for their learning and following their individual cognitive styles, interests, preferences. The students *learn how to learn.*
- The teachers are mostly facilitators, *co-learners*, persons ensuring the right educational resources at the right time, helping students get access to other relevant resources. They also diagnosis the students' problems, and help them any time when needed. The formative evaluation of students' achievements and evaluation based on project outcomes is dominant. The students are also encouraged to self-evaluation of their achievements and outcomes and are enabled to present them. (ICT offers new opportunities for *global student presentations*.) The teachers work both individually and in small groups with the students. They might be assisted by students-mentors who would help them and other students in using software tools.

Most of the mentioned principles give rise to some new developments both in educational science and in technology and provide a unique chance to start filling the gap between the advancements in the e-Learning research and the real university practice. Nikolov & Nikolova proposed a model for a *Virtual Environment for Distance Education and Training* (VEDET) that offers a comprehensive metaphor to be used both for human-computer interface and instructional design [35]. It also gives a paradigm for restructuring traditional education and training by complementing them with a virtual component. Thus the VEDET does not intend to replace the traditional school, university or training department, but rather extend their facilities and tools and make their activities more flexible and technologically enriched. VEDET offers a conceptual model of a virtual environment for open and distance learning that allows co-operation and training for a multicultural and multilingual virtual learning society. It includes an integrated virtual extension of the existing educational institutions and could serve as a virtual environment for distance education course development and delivery. In addition - it provides a common virtual research environment for some remote collaborative partners.

The most popular pedagogical model for teaching design is project-based learning – PBL, i.e. students to learn design by experiencing design as active participants [17]. The ability to work as an effective member of a development team is a primary goal of the SE education and one of the the main learning outcomes which the accreditation agencies and commissions would be happy to observe [40].

6. SOFTWARE ENGINEERING EDUCATION AT SOFIA UNIVERSITY

Faculty of Mathematics and Informatics (FMI) at Sofia University is a leading educational and research organization in the field of Informatics and Information and Communication Technologies (ICT). An internal university project for re-designing the computing curricula according the ACM/IEEE guidelines started four years ago. Following the ACM/IEEE CC2005 series recommendations [3] FMI has developed the BSc programs in: Computer Science [5], Software Engineering [4] and Information Systems [2] – see Figure 1. The main aims were to introduce some well established curriculum standards and new style of teaching. The main challenge was how to satisfy recommendations of the ACM/IEEE Computing Curricula, the Bologna Declaration, and several European ICT curricula recommendations [11], [12].

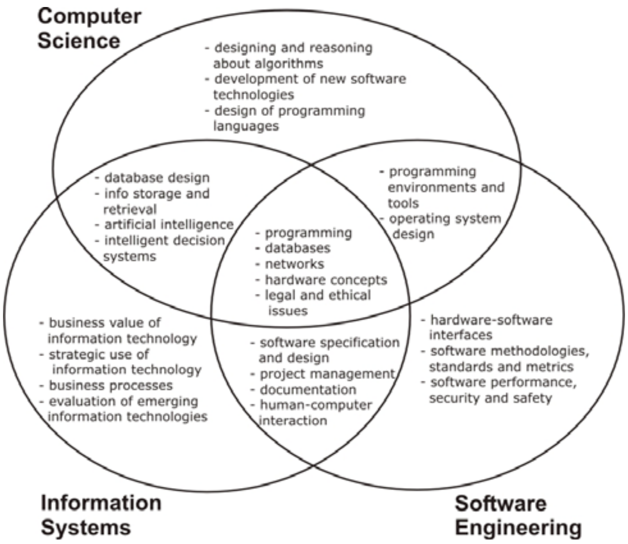

Fig. 1. Intersection of the BSc Computing Curricula in Computer Science, Software Engineering and Information Systems

Quality of education was considered as the major indicator for success while designing and implementing these programs.

6.1 Bachelor of Science Program in Software Engineering

The initial step of the Software Engineering Curricula Task Force at FMI was to create a vision and plan for curricula development. The development process consisted of three main phases – analyses, design and evaluation. More detailed information about those phases, real implementation and educational materials can be found in [36].

Comparing our BSc in Software Engineering program with similar programs in UK we can see that we are missing the 1 year placement. Instead of it we have internship at the end of the last year. The internship procedure we are accepted is following:

- FMI team contacts with Bulgarian private software companies and governmental organizations in order every three months to have updated pool of current requests for internship.
- That pool of requests is made available for students and they are supposed to apply for the preferable one
- In case of more then required applications for given request the selection procedure is started based on evaluation of students' skills and motivation. In some cases, depending on the company/organization, it is possible the requests to be extended to more people or event two teams to work in parallel on the same task.
- Every student has two tutors – one from the University and from the company
- Each internship ends with evaluation from the company tutor.

Usually after the internship students receive offers for full time position at the same company.

The other new schema for internships is in the process of establishment. It foresees internships in other European universities we are cooperating with for the work on national or European level real projects.

One way to have access to contemporary equipment and software is the strong cooperation with the ICT industry. A good example in this direction is the Sofia University Cisco Regional Academy, which was established in 2001 in order to implement the Cisco model of Public-Private-Partnership at a regional and national level. Similar cooperation programs were initiated with Microsoft (Microsoft IT Academy), Oracle (Oracle Academic Initiative), HP (HP training centre), SAP labs, IBM and other international IT vendors. The cooperation with the local ICT industry is considered as a strategic goal of FMI in order to better adapt the computing curricula according the needs of this industry, and to open doors for a professional carrier for every FMI graduate. Several bi-lateral programs for carrying out student internship programs with some local IT companies (e.g. Rila Solutions, Fadata, Technologica, Sirma, etc.) were established. The major Bulgarian ICT associations, such as BASSCOM, BAIT and ASTEL, also provide their services and support for achieving better cooperation between FMI and the Bulgarian ICT companies.

More detailed information about BSc program in Software Engineering is available on www.fmi-uni.sofia.bg.

6.2 Master of Science Program in Software Engineering

In addition, FMI offers large number of Master degree programs, such as Software Engineering, Information Systems, eBusiness and eGovernance, Artificial intelligence, Mobile Technologies and Distributed Systems, eLearning, Information Security, Mechatronics and Robotics, Computer Graphics, Computational Science and Engineering, etc.

Our SE Master program is result from the World Bank project "Market oriented master programs in Microelectronics, Software Engineering and Management" and started in 2004-2005 academic year. A number of strategic documents related to education in ICT and particularly in Software Engineering were reviewed, such as: Bologna process and Lisbon strategy, Carrier Space Industry Consortium, ACM/IEEE recommendations Industry companies – Intel, IBM, Microsoft, HP, etc - initiatives for Universities etc. Also a number of existing MSc programs in Software Engineering in Europe, USA and elsewhere were examined and compared. The needs of the Bulgarian ICT industry were also identified through a survey with a specially designed questionnaire followed by a number of individual meetings and discussions. In addition – a representative of the Bulgarian Software Association BASSCOM was associated to the FMI SE task force.

Last discussions about update of our Master program in SE involve two perspectives – research community and industry. From one side we analyze the recommendations and needs from specialized SE conferences like Model Driven Development, Requirements engineering, XP, etc. From other side as members of NESSI European initiative [39] we realized the need stated from industry for education of so called "T shaped" people – both deep and broad interdisciplinary education. Our strong believe is that at Master level students the main focus of teaching is problem solving abilities instead of facts learning.

The SE Master education at FMI is based on team work on class projects which are supposed to produce useful tools which are supposed to enrich either the software environment at the work place of the students or the SE educational environment. The students are involved in development, maintenance and refinement of real software that helps the students better understand the subject and adapt to a team work style. Some of the projects the students work on come from the research areas of the professors, and they might eventually evolve into diploma thesis. In some cases such project matures towards a PhD thesis as well. In other cases projects came from the current internal university needs. An example of such project is the eLearning Management System ARCADE [7], which was developed on a basis of team work of a team of four MSc students lead by a university professor. This system has been used as an eLearning platform for delivery courses at MSc level for more than six years now. The systems have been gradually extended and enriched with new functionalities and services and it was used as a basis for additional five MSc and two PhD works.

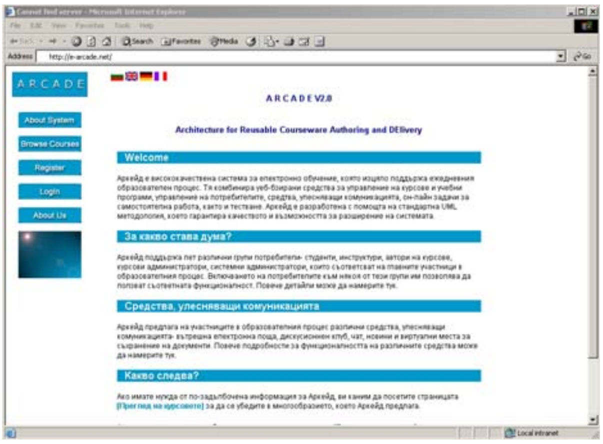

Figure 2. ARCADE – a Learning Management System developed as a team work of four MSc students

The ARCADE environment (Figure 2) has been designed and developed as a complex environment for a collaborative and active e-learning. Between its chief merits there are:

- It is based on standards – XML/XSL, Java, IMS, LTSC LOM, QTI, SCORM; UML widely use in development process
- Open - the use of XML import/export will make the system open for information exchange (including reusable courseware content) with other similar systems;
- Modular - different project modules are made as much independent as possible; easy plug-in of new functional modules;
- Portable – Java servlets and JSP technology plus MySQL or Oracle support make ARCADE portable between different platforms and operation systems.

Most of the MSc programs include compulsory internship student placement. The programs are oriented mostly towards needs of global ICT industry and the priorities of the European RTD Programmes in the field of ICT. In order to satisfy the ICT industry needs of technology managers Sofia University established a co-operation with Stevens Institute of Technology, USA, for local delivery of an MSc program in Information Systems [32]. An MSc program in Technology Entrepreneurship and Innovation is under preparation for the next academic year. Such measures would help the country to bridge the existing gap of ICT specialists and managers. The international cooperation opens new opportunities for improving the quality of education and for positioning Sofia University in the European Higher Education space. In process of negotiation and preparation are some joint Master degree programs with European universities, e.g. a MSc Program in Networked Computing together with University of Reading, UK. Other important activities in this direction are collaborations with Bolzen University for European Master Program in Sofware Engineering and with Malardalen University for Global Software Engineering – European Master. A strategic cooperation with many outstanding universities in the frames of the Intel Multi-core Computing Program opens new doors for international cooperation and adaptation of the Computing curricula according the most recent developments in the field and adapting it to some emerging technologies. Such international co-operation programs provide direct mechanisms for increasing the quality of education. They are very attractive for students and motivating for teachers.

6.3 Software Engineering research topics

As a natural consequence of all efforts in FMI in direction of SE a new department named Software Engineering was established on 1 March 2007. The main research topics aimed so far are:

- Software development processes and methodologies – We already had successful participation in European project named eXPERT in the filed of agile methodologies [Expert project]. Some important results are – development and application of new agile methodology, gap analyses and recommendations for implementation of agile methodology in SMEs with certified process, Bulgarian summer school on XP and Expert methodology; development of education materials and teaching of MSc course; one PhD student defended and currently one PhD student working in the filed of agile methodologies.
- Component based software engineering – our background is based on participation in European project named ECUA and strong cooperation with Malardalen University. Some results are: methods and models for description of non-functional properties of component architectures like reliability, formalization of requirements for application of buil-in testing in SAVE CCM model, specification on applications development framework based on the SAVE CCM component model; development of education materials and teaching of MSc course; one PhD student defended in the area of methods for component based architecture description and currently one PhD student working in the filed of Aspect Oriented Built-in-Testing on Component Based Software Systems.
- Software services – based on our NESSI initiative membership our future research interests are in software services and more specifically in modelling, simulation, and behavioural analyses of services ecosystems, SOA applications development process, SOA testing. One of our PhD students is currently working on approach for universal ontology-based services descriptions. Those descriptions should have characteristics like semantically expressive, automatically comparable, flexible, editable etc.

7. CONCLUSIONS

The future plans of the FMI include the following issues:

- Gradual increase of the number of enrolled BSc and MSc students in the ICT related programs;
- Development of a subset of BSc and MSc programs taught in English and marketing them on the regional level, mostly in the South-Eastern Europe;
- Development of partnership with other European and USA universities, including establishment of joint programs with dual degrees;
- Developing a complete educational virtual environment (Sofia University Virtual Campus) and increasing the courses and programs taught in e-learning mode;
- Establishment of a set of ICT research labs and further involvement of PhDs and other students in concrete research and technology development activities;
- Strengthening the innovation and entrepreneurship capacity of the university and establishment of strong technology transfer links with ICT industry and government;
- Extending the network of partnering organizations from ICT industry both locally and internationally and providing opportunities for cross-sector mobility of students, researchers, professors and ICT professionals.

We consider the educational change in the field of ICT at university level as being among the main factors for successful development of Bulgaria towards its way towards Knowledge Economy. In addition, the ICT education and professional development of ICT specialists turns to be a very strong factor for building a competitive country economy. Sofia University is prepared to take a leading role in this process.

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