An Overview of Organizational Approaches for Teacher Professional Development in Europe

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***Abstract*—** The importance of teacher professional development for improving the pedagogical competences of engineering teachers is being stressed in higher education institutions. In the context of the ongoing EXTEND project for the development of centers for teacher professional development in the Russian Federation and Tajikistan, was developed an analysis of current organizational approaches for improving engineering education and teacher professional development in the European Union. A set of 19 organizational approaches for teacher competence enhancement were identified and analyzed. The analysis resulted in two main recommendations to be developed in schools of engineering and that are being developed in the EXTEND project.

***Keywords*—** *Engineering Education, Centers for teacher professional development, Active Learning, Project-Based Learning*

I. Introduction

Engineering Education can be seen as the field related to the development of engineering competences of current or future engineers. It is related to the teaching processes of concepts, techniques, competences, attitudes and values related to the professional practice of engineering. In other words, it is related to the development of the capacity to mobilize all these resources in real contexts, to solve problems, using several areas of science and different technologies to support the society [1, 2]. Thus, this is an engineering interdisciplinary field interconnecting different knowledge areas of engineering, educational sciences, psychology amongst others. Educating engineers is an endeavour of a diversity of agents, including the students, the engineering teachers, all professionals involved in engineering related functions, students' peers and society agents. In this context, the role of the engineering teachers is extremely important, especially in formal university education activities, at all levels of training: initial, postgraduate and continuing. In this line of thought, for improving the engineering education field is important to give specific attention to the professional development of teachers [3].

The professional development of teachers is developed, in different schools of engineering, through organizational entities, which deliver training for teachers, give support to the engineering education research or for (re)designing innovative active learning approaches with students. The ERASMUS+ Capacity Building EXTEND project aims developing Centres in Higher Education institutions at the Russian Federation and Tajikistan with the support of four HEI from the European Union (EU). One of the activities of the Work Package 1 (WP1) of the EXTEND project is aimed to provide an analysis of best European practices in teaching engineering disciplines and best practices in teacher competence enhancement activities. The output of this analysis will be widely relevant to support and inspire the development of the EXTEND Centres. Thus, this paper aims to present an analysis of organizational approaches for teacher competence enhancement. This analysis is part of the ongoing EXTEND project and will contribute for supporting teaching professional development in engineering education, in terms of competences development and potential impact on teaching practice. Moreover, it will support the inventory of tools, methods and approaches utilized by European universities for teaching engineering disciplines in higher education institutions.

II. Context Background

The Bologna declaration and further the Budapest-Vienna Declaration (2010) encouraged strategies that enable student and staff mobility, improve teaching and learning in higher education institutions, enhance graduate employability and provide quality higher education for all. At the same time, the quality of education and student-centred learning are key landmarks in development of Universities [4, 5, 6]. In the EU, the modernisation of higher education has been acknowledged as a core condition for the success of the Lisbon Strategy (2000) and more recently the Europe 2020 strategy. The European Union has been preoccupied with harmonizing their higher education systems (which of course include engineering education as well), while also trying to preserve each country's identity.

The changes started from matching the regulatory framework and the structure of education programs. The processes of globalization, digitalization of society, cross-border flow of capital, goods, services, people and ideas, together with rapid technological developments, transforms occupations and the skills needed in the labour market. It creates pressure on Higher Education systems to respond quickly to changing skill needs and to renew their qualification requirements, training programmes and curricula.

Fourth Industrial Revolution is the digital revolution that has been occurring since the middle of the last century. It is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. The speed of current breakthroughs has no historical precedent. When compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. Moreover, it is disrupting almost every industry in every country. Digital fabrication technologies, meanwhile, are interacting with the biological world on a daily basis. Engineers, designers, and architects are combining computational design, additive manufacturing, materials engineering, and synthetic biology to pioneer a symbiosis between microorganisms, our bodies, the products we consume, and even the buildings we inhabit. And the breadth and depth of these changes herald the transformation of entire systems of production, management, governance and education [7]. Overall, the inexorable shift from simple digitization (the Third Industrial Revolution) to innovation based on combinations of technologies (the Fourth Industrial Revolution) is forcing Higher Education Institutions to re-examine the way they develop competences of both their students and their teachers.

The engineer of next generation will need to learn new technical information and techniques and embrace a whole realm of new technologies. Similarly, one must consider the several elements of the engineering education system, to include: the teaching, learning, and assessment processes that move a student from one state of knowledge and professional preparation to another state; students and teachers/faculty as the primary actors within the learning process; curricula, laboratories, instructional technologies, and other tools for teaching and learning; the goals and objectives of teachers/faculty, departments, colleges, accreditors, employers, and other stakeholders of engineering education; the external environment that shapes the overall demand for engineering education (e.g., the business cycle and technological progress); and a process for revising goals and objectives as technological advances and other changes occur [8]. Engineering education integrates research and practice to accelerate innovation and improve the quality and diversity of engineering graduates entering the professional world of engineering [1]. This field of knowledge is transversally related to all areas of engineering and have been gaining an exponentially increased interest in the last decade [9].

But despite obvious increase in attractiveness for young people engineering education is still facing many challenges in different countries. Post-socialist countries are witnessing dramatic changes in higher education caused by the transition toward a market-driven economy. Universities have had to adjust to a new life. They have needed to search for new sources of funding and involve teachers / researchers into entrepreneurial activities. The HE system of Russia has gone through a series of structural reforms in the past 20 years, notably moving within a still largely centralized system towards a greater university autonomy in the 1990s, and then through a reestablishment of federal control by means of new forms of state management. In 2003, Russia joined the Bologna process and went through a complex and radical structural transformation, replacing traditional diploma training (for engineers it took 5–6 years of training) with the two-tier system [10].

Obviously, these system-wide changes influenced Russian engineering education. It had big difficulties adjusting to the Bologna process but gradually many universities introduced two-tier programs in engineering. Moreover, they struggled with the lack of funding for new equipment and found creative ways to raise money through tuition and partnerships with business. There are a number of studies of the changes in the governance, structure and funding of engineering education [11, 12]. These studies demonstrate that almost all Russian engineering schools have adjusted their organizational structures to the new rules of the game. They have increased the intake of students in the market relevant areas and built partnerships with local, national and multinational companies. In 2006 about 22% of Russian students (more than 1.6 million) are enrolled in engineering and technical fields; this share has declined over the last decade (from 33% in 1995) [13]. Drop-out rate among students majoring in engineering is almost 25%, employment rates for bachelor graduates decreases due to unwillingness of industry to employ engineers with 4 years of education, teaching staff is ageing (average age – 52 years in RF and 56 years in TJK) and universities fail to create an effective system to retain young PhD graduates in engineering disciplines to perform teaching and research. One of the major unsolved problems behind these challenges is the deterioration of teacher training system in the universities and irrelevance of teaching methods employed for engineering disciplines. However, despite the problems and challenges engineering education faces in Russia in recent years, it begins to gain interest again. Thus, in 2015, 28.8% (153.3 thousands of people) of the total student enrolment in higher education were majoring in engineering (bachelor, master and PhD programs) in Russia [14].

According to the research conducted in the National Development Strategy of the Republic of Tajikistan until 2030, higher education, including the engineering discipline, is poorly integrated with scientific activities which adversely affects the quality of training and at the same time reduces the potential of preparing qualified specialists.

The EU universities have a large experience in the creation and implementation of modern teaching methods including project-based learning, practice-oriented approach, eLearning, student-centred approach and many others. It is very important in the context of new challenges to analyse the best European practices in teaching engineering disciplines and teacher competence enhancement and find out the solutions for transformation Engineering Education I other countries. This purpose is crucial in order to prepare future engineers to face the challenges of their practice. In fact, the professional practice requires the combination of different competences and, for that reason, they must be included in the curriculum [15]. However, the curriculum and the pedagogical practice are not always aligned with this purpose 16, 17, 18]. In short, for an understanding about the curriculum it is essential to understand it as a project that includes the teaching and learning experiences, the process of its development - design, development and evaluation - and the following key elements - objectives, content, resources, assessment and teaching and learning strategies [3].

The research in Engineering Education is strongly linked to the engineering fields [19] and to the improvement of education of engineers and the research interest is being even higher when referring to Active Learning in Engineering Education [20]. With this in mind, teachers must be prepared to create innovative learning contexts and to transform engineering education. For that, higher education institutions can provide approaches and structures for teacher professional development, in order to teachers be able to develop competences related to teaching practice.

III. Methodological Approach

In the scope of the EXTEND project, the diversity of approaches in teaching engineers to be analysed implies a definition of multiple sources and methods, as recommended by Wolf [21]. With this in mind, the team of the project used a methodological framework called Deming cycle (PDCA circle). The argument for choosing this methodological pattern is that Deming cycle is widely used in different areas in its original or modified form. Besides being an effective process improvement guide, it offers a systematic improvement method. The Deming cycle informs future improvement by providing feedback and maintains order during strategic planning, decision making and problem solving [22].

European best practices information were collected, including teacher development approaches and teaching methods used in training of engineers. For the aims of the project "a best practice" is defined as a relevant teaching and/or learning tool/method/approach/structure implemented in a real life setting in education of bachelor, master or PhD degree students majoring in engineering at one or several EU universities and which has been favorable assessed in terms of adequacy (ethics and evidence), effectiveness and efficiency related to process and outcomes. Other criteria are important for a successful transferability of the practice such as a clear definition of the context, sustainability, intersectorality and participation of stakeholders [23]. The best practices described meet also the follow requirements: a multidisciplinary approach, a breadth of education, leadership on the national level. Identification and selection of best practices were based on expert opinion from the project team members, both from European Union (EU) and Partner Countries (PC), following the criteria mentioned above. The list of best practices highlight that excellence in engineering education depends on structural and context issues. According to the approach, it was decided to consider examples of successful approaches of teaching professional development and of teaching methods in engineering education in EU. Two frameworks (templates) were defined for best practices review (depending on the methods/tools/approaches used in teaching engineering disciplines and teacher competence enhancement). Next step in carrying out the report is creating forms and choosing methods for analysis.

In Step 1 (Fig. 1), the team collected qualitative information about EU best practices in teaching engineering disciplines and teacher competence enhancement using the frameworks previously defined. It is important to highlight the fact that the best practices collected by the project partners were divided in two groups. The first group includes the Universities experience regarding organizational approaches to teacher professional development like setting up centres, platforms, networks and activities aimed at governance, research and development, Life Long Learning, internationalization and mobility, curriculum development and delivery, University Business cooperation. This dimension will be the focus of this paper. The second group

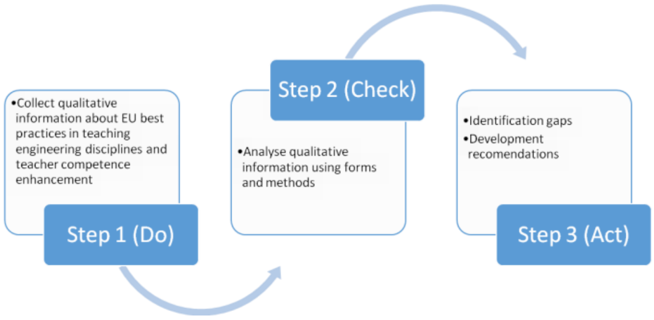

Fig. 1. Methodological steps

combines best practices focused on using a wide variety of active learning strategies [24]. In Step 2 an analysis of best practices was done, using two forms (according the frameworks) and content analysis. The forms allowed to collect qualitative data based on experts' opinion. This data was then analysed using content analysis strategies. For data analysis, a content analysis was carried out to identify recurring topics as well as contrasting patterns amongst teacher development approaches and teaching methods. Step 3 included identification of the gaps between the EU Universities best practices and Russian and Tajikistan realities in training engineers and development of recommendations for adaptation and possible dissemination of the identified European approaches in the practice of the Russian project partner universities.

IV. Findings

The findings of this paper will focus on the analysis of organizational approaches for teacher competence enhancement, based on 19 European best practices collected in the context of the EXTEND project. The table I summarizes the best practices analyzed and includes approaches from: Riga Technical University (RTU), University Polytechnic of Bucharest (UPB), Technical University Darmstadt (TUD), Karlsruhe Institute of Technology (KIT), University of Warwick (UW).

TABLE I. Summary of EU best practices analysed

COUNTRY/UNIVERSITY	TEACHER PROFESSIONAL DEVELOPMENT APPROACHES
Latvia/RTU	6
Latvia/RTU, University of Latvia, Switzerland	1
Nordic countries/Technical Universities	1
Germany/TUD	2
Germany/KIT	1
Global/Oracle	1
Romania/UPB	3
Sweden/ITU	1
United Kingdom/UW	3
TOTAL	19

A. Institutional Environment: Classification

After collecting the best practices, a classification was conducted considering the type of the organizational approaches for teacher professional development, namely centers, platforms, networks and activities (table II). Furthermore, each best practice was also classified considering the type of initiatives offered for teachers that was defined according to the dimensions identified in the literature: Research & Development (R&D), University Business Cooperation (UBC), Curriculum development and delivery (CDD), Internationalization and Mobility (I&M), Lifelong Learning (LLL), Recognition and Engagement (R&E).

TABLE II. SUMMARY OF THE EUROPEAN BEST PRACTICES IN TEACHER PROFESSIONAL DEVELOPMENT APPROACHES

University / Best Practices	Centers	Platforms	Networks	Activities
1. RTU/Engineering High School	Governance, LLL			
2. RTU/*Design* Factory	R&D, CDD, UBC			
3. RTU/Use Science		R&D, CDD, Governance		
4. RTU, University of Latvia / Center of High Energy Physics	R&D, CDD, I&M			
5. Nordtek Network			Governance, I&M	
6. RTU/Latvenergo Creative Laboratory	Governance, LLL, UBC			
7. RTU / Alumni Association			Governance	
8. RTU / International Week				LLL, I&M
9. TUD / INGENIUM - International Career Researchers	R&D, I&M			
10. TUD / Center of Educational Development and Technology	Governance, LLL, I&M			
11. KIT / From Graduation to professorship	R&D, LLL, I&M, UBC			
12. Oracle academy		R&D, CDD, LLL, I&M, UBC		
13. UPB/Summer Schools				R&D, UBC
14. UPB / Entrepren. Centre, UPBIZZ	CDD, I&M, UBC			
15. ITU			LLL, I&M	
16. UPB/Campus UPB	R&D, UBC			
17. UW/HE Academy Recognition	R&E			
18. UW/ International HE Academy & Award Teaching Excellence	R&E			
19. UW/ Education innovation Group	Governance, CDD			
	12	2	3	2

B. *Institutional Environment: Analysis*

A total of 19 best EU practices represent structural approaches. In 12 of them, it is possible to identify that centers are key structure for training engineers and teacher development. On the base of the centers all kinds of activities are performed: Research & Development, Governance, Curriculum development and delivery, Lifelong Learning, Internationalization and Mobility, University Enterprise Cooperation, Recognition and Engagement. Usually centers are structural units of the Universities. The RTU Best Practices 1, 2, 4 and The WU Best Practice 19 present experiences for setting up centers connected with different fields in engineering aimed to teacher competence enhancement and support the design/ re-design of new/revamped courses and innovations. For example, the Best Practice 1 is aimed at carrying out core pedagogical skills by teaching young high school children. In RTU Best Practice 2 the ability to apply teacher's theoretical knowledge to practical tasks, prototyping, testing new designs, working with advanced hardware and software solutions is showed. The Best Practices 4 and 6 are focused on Research & Development activity and the University Enterprise Cooperation as key drivers for boosting the next generation of technologies. Regarding to the TUD Best Practices (9 and 10) it is important to highlight that both cases deal with methodological upgrading that covers the provision of such services as: e-learning tools and methods, evaluation and counselling, interdisciplinary projects in the entry phase of studies, qualification for studies and careers via tutor qualification and key competence strategies. KIT Best Practice (11) is an example of the academic and research institution that focuses on research oriented teaching, strong science-industry relations and an internationalization edge. These targets are underpinned by consistent policy making likely to promote life-long learning, comprehensive advanced training, unrestricted exchange of know-how, and a sustainable innovation culture. It provides young scientists different kinds of support aimed at competence enhancement in all career phases, from graduation to professorship, by customizing offers to individual scientists with focus of interdisciplinary approach. UPB Best Practices 14 and 16 serves as an educational and research centers for students, teachers and scientists. They provide great opportunities for research and development activities based on multi – and inter- disciplinary technologies and collaboration between University and companies. Best Practices 3 (RTU UseScience) and 12 (Oracle Academy) refer to the resource facilities with open access to a variety of services, hardware and software to be used in engineering education. They are an excellent examples of collaboration between research personnel, scientific institutions and enterprises with the aim to develop the existing and create new competitive products and technologies with high added value. The Best Practices 5 and 15 is focused on the development of an international collaborative environment (network) for research, innovation and education within interdisciplinary areas providing clustering and knowledge exchange between technical universities, high tech industries and the local community in different development projects. Finally regarding to the Best Practices 7, 8 (RTU) and 13 (UPB) it is interesting to identify the examples of extra-curricular activities based on the developing contacts, knowledge and support. These activities facilitate cooperation among different stakeholders –students, teachers, alumni, Universities units, employees aimed at obtaining and reinforcing experience based knowledge. The WU Best Practices 17, 18 and 19 are aimed at recognition of the teachers who have made outstanding contributions to learning and teaching and spread effective learning and teaching behaviors around the university

V. FINAL REMARKS

The results of the analysis show that EU approach to creating the environment for teacher competence enhancement includes different types of initiatives that can inspire the EXTEND Centres. There are two main recommendations to reinforce from the analysis.

The first recommendation is related to the development of an institutional environment potential for teacher competence enhancement in Russian and Tajikistan Universities not only in the field of Research and Development but more actively in other fields (Governance, LLL, Internalization and mobility, Curriculum development and delivery, University Enterprise cooperation). The EXTEND centers could provide these opportunities. A comprehensive analysis of EU best practices selected for the aims of the project partially confirmed the impact of the institutional environment on the teacher competence enhancement. In nine of 16 organizational practices, it was possible to identify that centers are key structure for supporting innovative training of engineers and for teacher development. Centers develop a broad range large of activities - Research & Development, Governance, Curriculum development and delivery, Lifelong Learning, Internationalization and Mobility, University Enterprise Cooperation. Teachers in new innovative learning contexts should develop active Learning approaches and Project-Based Learning is one of the strategies most referred and with a broad learning impact.

The second recommendation focus on how Higher Education Institutions can support and promote continuous professional development of teachers, for sustaining the change of teaching and learning methods in direction of more effective approaches. The great majority of higher education (HE) teachers in Russian and Tajikistan Universities did not have pedagogical training previously to engage in their professional activity as teachers. Nevertheless, there is currently a strong trend on continuous professional development of teachers. It is important to highlight the necessity to develop institutional environment and provide sustaining continuous evolution of active learning methods in engineering education. The EXTEND centers set up within the project will contribute to strengthening mastery of active learning methods and best pedagogical practices in engineering education.

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