What can be recommended to engineering teachers from the analysis of 16 European teaching and learning best practices?

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Conference Key Areas: another topic relevant to the conference

Keywords: Engineering Education; Best Practices; Active Learning

ABSTRACT

European Higher Education institutions have been implementing active learning strategies in different contexts. In order to learn and disseminate these approaches, it is important to understand how these successful active learning strategies can be implemented in new contexts.

The EXTEND ERASMUS+ project aims to develop Engineering Education Centres in Russia and Tajikistan in order to make a contribution for the development of these countries' schools of Engineering. One of the first steps in pursue of this objective is the study of European teaching and learning best practices and the definition of a set of useful recommendations for the teachers of Engineering schools. A question raised by this approach was what can be recommended to engineering teachers from the analysis of teaching and learning best practices? The objective of this paper is to

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develop a method for the analysis and recommendations and to present the results of the application of this method in 16 European teaching and learning best practices.

The method was qualitative and developed by brainstorming between experts of the projects from different areas of knowledge. This method included the definition of a glossary, selection of best practices, collection of the information, analysis in relation to the best practices, analysis of maturity levels regarding the current level of partner countries and development of collaborative recommendations.

The main recommendations for the Russia and Tajik contexts are to develop Project Based Learning approaches in interaction with industry, and additionally for Tajik partners to develop entrepreneurial and management competences in engineering students.

1 INTRODUCTION

The Bologna process aims to improve the European Higher Education (HE) system, contributing for a better transition of graduates to professional practice, through the introduction of new or more effective approaches for international mobility, quality of HE systems, and innovative curricula, including teaching and learning strategies inspired by Active Learning. Thus, the modernization of the HE systems has been acknowledged as a core condition for the success of the Lisbon Strategy (2000).

Post-socialist countries are going through dramatic changes in higher education, caused by the transition toward a market-driven economy. HE institutions start looking for new sources of funding and involving teachers / researchers into entrepreneurial activities. Russia joined the Bologna process in 2003 and went through a structural transformation of traditional training for engineers of 5 to 6 years, toward a two-tier system [1]. According to the research conducted in the *National Development Strategy for development of the republic of Tajikistan until 2030* Engineering training is poorly integrated with scientific activities and interaction with the external companies, which adversely affects the quality of training and at the same time reduces the potential of preparing qualified specialists [2]. An EU funded project in the frame of ERASMUS + aims to enhance the capacity of HEIs in Russia and Tajikistan in engineering education. The EXTEND project aims to launch Engineering Education Centres to develop teacher competences and improve the quality of education in engineering disciplines.

As EU universities have a large experience in the creation and implementation of innovative student-centred approaches to teaching and learning activities, the analysis of EU best practices will contribute for the development of useful recommendations for both Russian and Tajik HE institutions. Nevertheless, the analysis of best practices raises questions related to what can be recommended to engineering teachers from the analysis of teaching and learning best practices? The objective of this paper is to develop a method for the analysis and recommendations and to present the results of the application of this method in 16 European teaching and learning best practices.

2 METHODOLOGICAL APPROACH

In order to have a good grasp of the European best practices, there is the need to collect and analyse information about a large set of best practices on teaching and learning strategies. Thus, a list of best practices, based on Active Learning practices or approaches, was created. These were chosen considering recommendations from project experts, availability of information in web sites and publications and available capacity to process the information. It should be noted that this list does not have the intention to cover all best practices, but has the intention to create a good perspective on different innovative approaches being developed in the European context. After defining the list of cases, there was the need to develop a glossary to increase the coherence of the analysis and a form for selection of the most important information to extract from each case. Finally, a maturity model methodology was applied for classification and analysis of the best practices.

2.1 Methodology steps

Fig. 1 presents a process model followed by the team, during the collection and analysis of the information. In Step 1 the team collected qualitative information about EU best practices in teaching engineering disciplines using the frameworks previously defined. Step 2 is related to the analysis of best practices collected using a form (according the framework) and content analysis. The form 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 [3]. 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. This step used a maturity grid as an assessment tool.

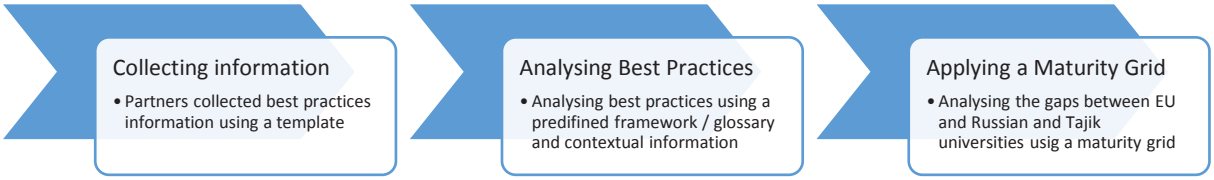

Fig. 1. Execution, analysis and development phases

2.2 Glossary

For the aims of this work, "a best practice" is defined as an Active Learning 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 favourable 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 [4]. The best practices described in the chapters below meet also the follow requirements: a multidisciplinary approach, a breadth of education, leadership on the national level. Finally, identification and selection of best practices were based on expert opinion of project team members following the criteria's mentioned above, the availability of information and the available capacity for

processing the information. The list of 16 best practices provided was created for further analysis.

The best practices focused on using a wide variety of active learning strategies, which were classified and defined according to a predefined glossary (*Table 1*). Active learning is an approach to learning in which teaching is prepared in order to engage students in the learning process, by creating meaningful learning contexts. These learning contexts allow students to understand the relevance of *what* they learn and *what for*. An Active learning environment includes enthusiasm, energy, engagement and action. Critical thinking about learning is also a key-issue [5];[6];[7];[8] Different methods and principles can be implemented as Active Learning strategies, as referred by [9].

Table 1 presents active learning strategies classified and defined as: Problem-Based Learning (PBL); Project-Based Learning (PBL); Gamification; Team Based Learning; Work Based Learning; Research Based Learning. This list represents some of the most common active learning approaches but some other approaches can be considered during the analysis phase.

Table 1. Glossary of Active learning strategies

CONCEPT	DESCRIPTION
Problem-Based Learning (PBL)	Is an educational approach whereby the problem is the central point of the learning process [10]. The type of problem is dependent on the specific learning environment, but are usually presented as a case, based on a real life issue or a realistic approach. The problems are selected and edited to meet educational objectives and criteria. It is crucial that the problem serves as the basis for the learning process, because this determines the direction of the learning process and places emphasis on the formulation of a question rather than on the answer. This also allows the learning content to be related to the context, which promotes student motivation and comprehension. It is essential that the directing force is consistent with the way the assessment drives the educational method.
Project-Based Learning (PBL)	Is a Problem-Based Learning approach, in which teams of students must develop a solution for a problem. Thus, this also an approach based on real life issues, where the problem is ill defined and the students must be able to define the problem before developing the project solution. Dealing with an open problem, teams of students can develop several different solutions that may not even be expected by the teachers [11];[12]; [13]). Teachers act as coaches, mentors or supervisors, depending on the phase of the project and the specific learning environment. In most situations, a Project-Based Learning approach is developed during a period of time longer (e.g. semester) than Problem-Based Learning (e.g. 4 weeks) [14].
Gamification	Gamification is the use of game design elements characteristic for games in non-game contexts, in order to o increase user experience and engagement. This is not the same as serious games because the learning activities may not include simulation nor competition [15].
Team Based Learning	Team-Based Learning is an evidence based collaborative learning teaching strategy designed around units of instruction, known as “modules,” that are taught in a three-step cycle: preparation, in-class readiness assurance testing, and application-focused exercise. A class typically includes one module [16]. TBL combines small and large group learning by incorporating multiple small groups into a large-group setting [17].
Work Based Learning	Is the term being used to describe a class of university programs that bring together universities and work organizations to create new learning opportunities in workplace. Typically, this may include the following types of activities: visits to professional places, networking interaction opportunities, and project-based learning approaches in interaction with external organizations [18].
Research Based Learning	Curriculum is designed around inquiry-based activities in order to create and develop new knowledge. The focus of learning through inquiry; the teacher-student division minimized and students are engaged in research practice [19]; [20] .

2.3 Maturity grid

For the aims of analysis of maturity levels regarding the current level of using active learning strategies by Russian and Tajik universities a maturity grid developed by Ph. Crosby (Crosby, 1979) has been choosing. It provides the opportunity to identify what might be regarded as good practice (and bad practice), along with some intermediate or transitional stages [21]. The maturity grid has a strong evolutionary theme, suggesting that organizations are likely to evolve through five phases - Uncertainty, Awakening, Enlightenment, Wisdom, and Certainty – in their ascent to the excellence. This can be analysed from uncertainty, no comprehension of the necessity in using the method, to certainty, proficiency and sustainability in using and applying the method. The using of this tool allows to distinguish the gaps between the European and Russian practices and approaches in training engineers.

2.4 Data Collection Summary

The 16 cases of teaching and learning best practices analysed in this study are summarized in Table 2.

Table 2. Summary of the European best practices in using Active learning strategies analysed in this study

University / Best practices*	Problem Based Learning	Project Based Learning	Gamific. / Serious Games	Team Based Learning	Work Based Learning	Research Based Learning	Other
1. AAU/PBL	X	X					
2. CUT/MMPE			X				
3. DTU/ENG		X				X	
4. DUT/ENG							X
5. IPG/IE					X	X	
6. MU/DATA		X					
7. TU/SENG							X
8. UCL/IEP		X					
9. UMinho/ENG		X					
10. UMinho/IEM-IM41		X					
11. UMinho/IEM-IM11		X					
12. UMinho/LEAN			X				
13. UW/APPR					X		
14. UW/DES							X
15. UW/REFL							X
16. UW/SELF							X
Total	1	7	2		2	2	5

* UMinho/IEM-IM41 - University of Minho (Portugal) / Industrial Engineering and Management Integrated Master (4th Year, 1st semester). UMinho/IEM-IM11- UMinho / Industrial Engineering and Management Integrated Master (1th Year, 1st semester). UMinho/ENG - UMinho / Engineering Programs. UMinho/LEAN - UMinho / Lean management courses. CUT/MMPE - Częstochowa University of Technology (Poland) / Master in Management and Production Engineering. DUT/ENG - Delft University of Technology (Netherlands) / Faculties in engineering, applied science and design. AAU/PBL - Aalborg University (Demark) / Educational programs adopted a purely Problem-Based Learning (PBL) approach. UCL/IEP - University College of London (UK) / Integrated Engineering Program. IPG/IE – Institut Polytechnique de Grenoble (France) / Master in Industrial Engineering – Sustainable Industrial Engineering program. DTU/ENG – Technical University of Denmark (Denmark) / General Engineering programme (BSc). TU/SENG - Tampere University (Finland) / International Degree Programme in Science and Engineering, BSc. MU/DATA - Maastricht University (Netherlands) / Data Science and Knowledge Engineering. UW/APPR - University of Warwick (UK) / Engineering Degree Apprenticeship. UW/SELF - UW / Self-Assessment. UW/DES - UW / Signature Pedagogies & Design Thinking. UW/REFL - UW / Reflective Practice & Learning Logs

Finally, an integrated discussion and recommendations was developed and presented in the last section of the paper.

3 BEST PRACTICES ANALYSIS – ACTIVE LEARNING STRATEGIES

For the aims of the study, 16 best practices were selected among European universities. For 7 of them, PBL model is defined as dominating. At the same time a wide range of strategies such as work based/ research based / problem based learning are used. In order to have a better grasp the teaching and learning experiences of the European universities, some common elements were identified amongst them.

First, all PBL models described present an interdisciplinary approach, which could happen between different areas of one program, or between different programs. For instance, the project development in the context of best practices represented by University of Minho (best practices 9 and 10 in Table 2), includes incorporating the knowledge and competences inherent to all courses studied by the students in the semester, which implies a collaboration amongst the course teachers. It is worth mentioning that PBL analysed in the best practices of European contexts, is used in different years of the programs, both in early and advanced semesters. The difference is in the content of the approach. What is specific for the first semester is that it is usually based on basic sciences with a realistic problem related to the professional practice. Applying PBL in more advanced semesters implies more autonomy from the teams of students and much more responsibility of the students for the solutions resulted in the projects.

Second, most of PBL models include close collaboration with internal and external stakeholders. The coordination team usually includes teachers, tutors and educational researchers from different schools/departments maintaining a wide diversity of ideas and experiences. In some cases, e.g. case of University College of London (best practice 8 in Table 2), special universities units provide students with teaching, learning and training support within the project development. Collaboration with companies, high schools or media partners within project development allows to open the university to “outside”, providing suggestions and solutions for real problems. For that reason, collaboration is a key/element in these models, not only in terms of collaboration between team members, but also with other stakeholders.

Some cases show a great combination of active learning strategies. For instance, the experience of Aalborg University (best practice 1 in Table 2) is focused on Problem Based Learning with project work based on authentic problems. It offers complex environment, engaging students in real contexts and provides them the opportunity to participate in interdisciplinary activities and develop their professional skills in the real-word.

Serious games and Gamification are approaches implemented at University of Minho and Częstochowa University of Technology (best practices 2 and 12 in Table 2) implies to use different type of equipment, tools and materials and has a strong hands-on simulation nature. In this context, students can visualize, touch and reflect about the content through the experience of learning by doing. Thus, students plunge into real practice through the hands-on approach.

Best Practices presented by Institute Polytechnique de Grenoble and University of Warwick (best practices 5 and 13) focus on work-based learning which is quite related to the practicum. In this case, external stakeholders are also actively involved in tutoring and mentoring of student’s projects. Students are encouraged to go inside of an industrial company or a research institute, during one semester to focus on a research problem or develop an innovative idea.

The case of Tampere University (best practice 7 in Table) presents an Active Learning approach, in which students are challenged to work in both ways - independently

focusing on their own needs, motivations and expectations and taking responsibility for their studies in close collaboration with their fellow students communicating and working as part of a group. There is a wide range of activities that can be selected: workshops, events, conferences, social projects, etc. Finally, best practices 14, 15 and 16 in the Table 2 provided by University of Warwick are focused on developing student's imagination and creativity, empowerment and engagement.

4 DISCUSSION AND RECOMMENDATIONS

The results of analysis of 16 European universities best practices in using active learning strategies show their diversity and potential for dissemination, regarding the identified approaches, into the Russian and Tajik Higher Education Institutions. The study was also aimed at identifying the gaps between the EU universities best practices and Russian and Tajik realities in training engineers. It is necessary to highlight the importance for implementation of active learning strategies in the Russian and Tajik universities based on the current requirements for the competences of engineers. Applying the active learning strategies at the advanced level requires well-developed institutional environment [22]. In terms of active learning strategies, all types of methods and tools presented in EU universities cases are used by Russian and Tajik universities but the levels of maturity in applying them are much different (Table 3).

Ranking active learning strategies reveals that most of methods are not new for Russian and Tajik universities and tend to the levels of Awakening and Enlightenment. With this in mind, a set of recommendations are proposed.

First of all, it is necessary to develop active learning strategies such as Problem-Based Learning, Project-Based Learning, Gamification, Team Based Learning, Work Based Learning and Research Based Learning in Russian and Tajik universities in a more effective way. One of the main results of this study shows a strong focus of the European engineering programs on Project-Based Learning (7 out 16 examples). At the same time a wide range of strategies such as Work Based/ Research Based/ Problem Based Learning are used. PBL models described present an interdisciplinary approach. Most of them include close collaboration with internal and external stakeholders. The coordination team usually includes teachers, tutors and educational researchers from different schools/departments maintaining a wide diversity of ideas and experiences.

The active learning strategies Maturity Grid with regard to Russian and Tajik universities practices shows the gap in using these methods. Most of them are at the low or medium levels due to barriers of institutional nature. Regarding to Tajik universities reality the main obstacle is weak human resource i.e. low qualified teachers and insufficient technical capacity. Moreover, it should be noted that there is no clear system for organizing advanced training and retraining of teaching staff in engineering subjects in Tajik universities. It is needed to enhance entrepreneurship and management as additional competences among students in engineering fields. In this context, Problem and Project Based Learning and Gamification are effective learning methods to develop the competences of engineering students.

Secondly, it is important to implement active learning strategies with strong University Enterprise collaboration to get closer to the needs of realities and future challenges in industry. One of the emerging trends recognized in the conceptual background is the need to create explicit curricular links with external agents, namely with industrial companies. The European Union initiative, University-Business Cooperation (UBC) [23] describes the need to develop graduates' competences aligned with the needs of the labour market. The interaction between engineering educational programs and external agents incl. industrial companies can be developed by visiting industries,

invite professionals or key agents of the society to deliver seminars, integrate internships and work-based learning in the curricula, or developing projects to deal with real industrial or society problems [24]. Some of the best practices show interactions with industrial companies or other external stakeholders. Therefore, strategic partnership will shift to more mature levels of using active learning strategies. Thirdly, Higher Education Institutions should support and promote continuous professional development of teachers, for sustaining the change of teaching and learning methods in direction of more effective approaches. 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 centres set up within the EXTEND ERASMUS+ project will contribute to strengthening mastery of active learning strategies and best pedagogical practices in engineering education. Thus, the main recommendations for Russian and Tajik universities are to develop active learning strategies, especially Project Based Learning approach in interaction with industry, and additionally for Tajik Universities to develop entrepreneurial and management competences of engineering students.

Table 3. Active Learning Strategies Maturity Grid with regard to Russian and Tajik Universities practices

METHOD		AWAKENING	ENLIGHTENMENT	WISDOM	
Problem-Based Learning (PBL)			While going through teaching and training, learn more about the method benefits. (RUS, TJK)		
Project-Based Learning (PBL)		Recognizing that the method may be of value but insufficient competence of the teachers is an obstacle for making advances (TJK)	While going through teaching and training learn more about the method benefits. (RUS)		
Gamification		Recognizing that the method may be of value but not willing to use it (RUS)	While going through teaching and training learn more about the method benefits. (TJK)		
Team Based Learning	UNCERTAINTY	Recognizing that the method may be of value but not willing to use it (RUS, TJK)			CERTAINTY
Work Based Learning			While going through teaching and training learn more about the method benefits. (RUS, TJK)		
Research Based Learning		Recognizing that the method may be of value but the technical capacity is limited to use it (TJK)		Implementing and deployment the method at all levels of the educational programs (RUS)	
Various approaches (combination of previous methods)		Recognize that the methods are of value but limited technical base and low competences to use them (TLK)	While going through teaching and training learn more about the method benefits (RUS)		

* RUS- Russian universities, TJK - Tajik universities

5 ACKNOWLEDGMENTS

This work is based on outcomes of the project EXTEND – "Excellence in Engineering Education through Teacher Training and New Pedagogic Approaches in Russia and Tajikistan" that has been funded with support from the European Commission (Project Number: 586060-EPP-1-2017-1-RO-EPPKA2-CBHE-JP). This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein. The authors would like to thank to the members of the consortium and all that made possible to collect the data we used in this paper.

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the Project Scope UIDCEC003192019.

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